

DOCUMENT RESUME

ED 279 547

SE 047 819

AUTHOR Tisher, Richard P., Ed.
TITLE Research in Science Education, Volume 16. Selections of Papers From the Annual Conference of the Australian Science Education Research Association (17th, Adelaide, South Australia, May, 1986).
INSTITUTION Australian Science Education Research Association.
PUB DATE 86
NOTE 246p.; For volume 15, see ED 267 974.
AVAILABLE FROM Prof. Richard T. White, Business Manager, Faculty of Education, Monash University, Clayton, Victoria, 3168, Australia.
PUB TYPE Collected Works - Conference Proceedings (021)
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Cognitive Processes; Computer Uses in Education; Foreign Countries; *Learning Strategies; Misconceptions; Piagetian Theory; *Science Curriculum; Science Education; *Science Instruction; *Science Teachers; Sex Differences; Teacher Education
IDENTIFIERS *Australian Science Education Research Association; *Science Education Research

ABSTRACT

Selections of papers from the seventeenth annual conference of the Australian Science Education Research Association are presented in this volume of Research in Science Education (RISE). A diversity of themes are addressed and include new topic areas as well as concerns that have been cited in previous issues of RISE. The papers focus on such themes as: (1) gender differences in science education; (2) action research projects associated with learning in science; (3) curriculum frameworks; (4) computer simulations; (5) Piagetian concepts; (6) nature of students' questions; (7) research on science teacher education; (8) misconceptions of science phenomena; and (9) schematic representations of knowledge. Also provided are research notes, the addresses of the authors of the papers, and guidelines for submission of the papers. (ML)

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RESEARCH
IN
SCIENCE EDUCATION

Volume 16

Selections of refereed papers from the Seventeenth Annual Conference of the Australian Science Education Research Association, St. Ann's College, Adelaide, South Australia, May, 1986.

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Published by Australian Science Education Research Association.

ISSN 0157-244X

Printed by Monash University Printery, Clayton, Victoria,
from camera-ready word processor copy prepared by Dandy Words, Narre Warren North.

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PREFACE

Research on science education continues to flourish and this issue of R.I.S.E. has been increased in size in order to accommodate and illustrate the diversity of activity in Australia and elsewhere. This issue contains a diversity of themes which provide a rich smorgasbord for the reader.

There are two papers dealing with gender differences in science education in Thailand and Kenya, two dealing with action research projects associated with pupils' learning in science (i.e. the LISP and PEEL projects), one associated with the curriculum frameworks proposals in Victoria, another on computer simulations, several on classroom strategies, one related to Piagetian concepts and schematic representations of knowledge and, once again, a larger cluster (about seven) dealing with students', trainee teachers', teachers' and other adults' science concepts, memory structures and misconceptions.

That is not the complete smorgasbord since there are several newer themes appearing in other papers. For the first time there is a report of a pilot project to study the nature of the questions pupils ask, a theoretical analysis of the nature of explanation and two attempts to provide theoretical underpinnings to research on pupils' learning in science. Two papers re-introduce themes that were current several decades ago by referring to teachers' constructs of able students and the attributes of exemplary teachers. In the remaining papers readers are given details about conditions of science learning in Canada and provided with some new challenging directions for future research in science education.

Richard P. Tisher

Editor

Research In Science Education, 1986, 16, 1-10.

CREATIVE LEARNING IN SCIENCE EDUCATION

Jan Garrard

INTRODUCTION

How does it happen there are people who do not understand science? If science invokes only the rules of logic, such as are accepted by all normal minds; if its evidence is based on principles common to all men, and that none could deny without being mad, how does it come about that so many persons are here refractory?

(Paraphrased from a quotation by Henri Poincare, approx. 1900, reproduced in Newman, 1956, p. 2041.

The original quotation referred to mathematics.)

In the 1980s, no less than in 1900, this question continues to intrigue us. Over the past 80 years, many philosophers, psychologists, and educators have attempted to answer this question in their own ways. In this paper I suggest that contemporary learning theories do not address the whole thinking, feeling, and socially interacting student, and further that the cognitive learning processes have been seen in terms which are too narrowly logical and analytical.

Non-analytical processes in original scientific discovery have been well documented (e.g. Ghiselin, 1955), but virtually ignored by philosophers of science who have focused on the experimental phase of scientific research (Hodson, 1985). Thus, philosophers of science analyse in depth the various inductive, deductive, critical, and demonstrative processes which are seen as the vital steps in the production of scientific knowledge, and largely ignore the individual creative phase of scientific research. In the words of Arthur Koestler:

The role of strictly rational and verbal processes in scientific discovery has been vastly overestimated since the age of enlightenment. There are always large chunks of irrationality embedded in the creative process, not only in art (where we are ready to accept it) but in the exact sciences as well.

(Koestler, 1964, p. 14)

Not only does creativity lie at the heart of original and innovative scientific research, it is also an essential ingredient in learning about science. Thus, parallels have

been drawn between the scientist actively seeking new concepts, theories, etc. which are presently unclear, and the student seeking to understand for himself or herself existing scientific findings which are from the student's perspective, just as new, confusing, and uncertain.

According to Bruner (1966):

There is a continuity between what a scholar does in the forefront of his discipline and what a child does in approaching it for the first time.

On the other hand, some educational psychologists insist that creativity involves the production of something new and insightful for the culture, rather than simply the production of an idea that is new to its creator.

For example, Ausubel (1968) states:

Only the rare individual who makes a singularly original and significant contribution to art, science, literature, philosophy, government, and so forth, can be called a creative person (p.552).

In this paper, the former position is adopted; namely, that the learner who actively constructs, generates or creates his or her own understanding is viewed as a creative thinker. I argue that the creation of meaning by the presently naive, but actively seeking student, is an integral component of learning about science. Learning cannot be described purely in terms of linear, rational, and analytical processes. Imagining, feeling, experiencing, intuiting, etc. are integral components of both scientific enterprise and learning about scientific knowledge. Further, in the real world of school learning (as contrasted with laboratory studies of cognition) it is the whole student who engages in learning, and the cognitive processes of learning cannot be separated from the motivational and social aspects of learning. Therefore my discussion of cognitive learning is embedded in a model of interactive cognitive, motivational, and social variables in learning.

DISCUSSION

The social learning theorist Albert Bandura (1977a) explains human behaviour in terms of continuous, reciprocal interactions between personal (P), behavioural (B), and environmental (E) variables. He uses the triangular representation:  to stress the complex interrelationships between these variables.

I have adopted a similar model to describe the learning process in terms of three interrelated factors: motivational (M), cognitive (C), and social (S). The interactive triangle then becomes: . These three factors represent phases in the learning process that I will describe in a serial, mainly verbal manner. I hope the interactive diagram counteracts the impression that the order in which I describe them is invariant. Also, I intend to be selective rather than comprehensive in describing aspects of the

motivational, cognitive, and social phases in the learning process. I have chosen to focus on factors that I believe have been neglected by science educators.

Motivational processes - 'What shall I do?'

Noddings and Shore (1984) suggest that there are two phases in a learner's approach to new observations, experiences, or information. They propose that the cognitive question 'what is it?' is preceded by the mainly affective question 'what shall I do?'. 'What shall I do?' is a more specific motivational question than the more general sense in which the concept of motivation is frequently used in educational psychology. 'What shall I do?' does not denote a general predisposition to learning or to particular subjects or topics. It is a specific response to a specific learning task. 'What shall I do?' is an immediate emotional response to the learning task, and the subsequent intellectual question of 'what is it?' will be addressed only when we feel safe enough to ask it. According to Noddings and Shore (1984):

The feeling that accompanies this state is discomfort. We are impatient, uncertain that anything will be accomplished, afraid that interruptions will occur, edgy, doubting our own capabilities ... We would like to avoid this looking that may or may not result in seeing (p.88).

This position suggests that a student's initial interaction with new learning can be seen as one of approach/avoidance. Many of the learning models currently used in science education see students as primarily motivated by intellectual curiosity and/or the need to understand, predict or control their environment and tend to neglect the 'avoidance' factors that might prevent a student from even beginning to tackle the 'what is it?' question. Some constructs from clinical psychology and from social learning theory may point to some of these factors.

A movement in clinical psychology which adopts a 'cognitive' approach to emotional disorders is the rational-emotive therapy or cognitive therapy approach of Beck (1976) and Ellis (1962). Cognitive therapists use the concept of 'self-talk' to indicate that when individuals are depressed or anxious they are thinking and therefore talking to themselves in an illogical, negative manner which leads them to act in self-defeating ways. Cognitive therapy utilizes techniques for helping people to change their emotions by changing their self-talk (Burns, 1980).

In a similar vein, Bandura (1977b) identifies two 'self-efficacy' determinants of behaviour: (i) an 'outcome expectancy' which is an individual's estimate that a given behaviour will lead to certain outcomes, and (ii) an 'efficacy expectation' which is the conviction that one can perform the behaviour required to produce the outcomes.

When learning is viewed as an active constructive, generative, or creative process the affective components of coming-to-understand cannot be ignored. These factors are not simply the precursors of the learning process which can be viewed separately from the

'real nuts and bolts' of learning - the cognitive processes. Self-talk involving questions such as: Am I the sort of person who usually succeeds in understanding? Is this proposition understandable? Can I understand it? Is this piece of learning important to me? Is the effort of attempting to understand going to pay off? are integral components of the sense-making process and occur at all stages of coming-to-understand. They cannot be separated from the overall learning process as suggested by educators such as Posner et al. (1982) and Novak (1977). Indeed, many educators have focused on so-called affective learning and stressed that self-actualisation, self-realisation, and personal growth, autonomy, and responsibility should be the primary aims of education in order that students can approach 'what is it?' in a confident, meaningful manner (e.g. Rogers, 1969; Brown, 1971; Brown, 1975).

Cognitive processes - 'What is it?'

This area is the focus for much of educational psychology particularly when applied to science education. In this section I suggest that there are many different cognitive processes, some of which can be viewed as analytical processes and others as more holistic processes.

(a) Analytical processes

Massialas and Zevin (1983) define analytical processes as: 'the conscious processes through which alternative hypotheses are tested and confirmed. The process is generally characterized by cautious step-by-step methods and by conscious avoidance of logical, psychological, and material fallacies and pitfalls' (p.10).

Analytical thinking, like scientific experimentation, is concerned with the breaking down of wholes into more manageable parts. In educational terms it is associated with the work of Dewey (1933) and his five phases of reflective thought which were designed to ground belief through the use of reason, evidence, inference, and generalization. Similarly, Piaget's (1964) formal operations, Gagné's (1965) bottom-up learning hierarchies and Novak's (1977) top-down concept maps all view learning in terms of acquiring hierarchically organized knowledge by the step-by-step, logical application of mental processes.

According to Massialas and Zevin (1983) these views present an idealized picture of the logical steps in thinking but they do not take into account how individuals really think and learn from the psychological viewpoint. As Shuell (1985) notes, this debate is still current in science education.

(b) Holistic processes

In contrast to analytical processes, holistic thinking processes involve playfulness, fantasy, and irrationality. They can be more haphazard, proceed in leaps and bounds, backwards and forwards; they can bring novel, surprising, seemingly unrelated, distant

experiences and images into a learning situation which has become bogged down by restricted, analytical thinking.

Hadamard (1954) distinguishes between 'cogito' meaning to 'shake together', and 'intelligo' meaning to 'select among':

Cogitation and intelligence: the one refers to letting one's ideas, memories, impulses, fantasies rise freely; the other refers to the superimposed process of choosing from among unanticipated combinations those patterns which have significance in reality. The 'cogito' component of creative thinking seems predominantly an impulsive or preconscious process, the 'intelligo' component a predominantly reflective or conscious process (p.29).

While the 'intelligo' processes have been described in detail by philosophers, psychologists, and educationists, it is much more difficult to articulate the processes of 'cogitation' or, in my terms, 'holistic thinking'. How does one catch oneself or someone else in the act of 'cogitation'? Indeed, how would one describe such a 'shaking together' in logical, analytical terms?

This dilemma has led many creative individuals to attribute their insights to divine intervention or to subconscious processes (Ghiselin, 1954). More often, however, creative insights are seen in terms of a pre-conceptual or 'experiential' understanding (Richardson, 1984), something which is apprehended with the mind but not yet articulated, which is felt, experienced, or intuited rather than conceptually understood.

Recent research in neuropsychology has helped to move creative thinking processes away from the realm of the supernatural or the subconscious and more towards the area of cognitive psychology. For example, research into brain functioning has shown that the right and left hemispheres of the brain process information somewhat differently (Williams, 1983). Although some of the extreme dichotomies proposed during the early heyday of left/right brain research such as art/science, reason/intuition, and cognition/emotion are probably oversimplifications, comparisons of left and right brain functioning offer valuable insights which can aid a more comprehensive view of mental functioning.

Williams (1983) summarises research into human cerebral asymmetry as indicating that we possess two different but complementary ways of processing information: verbal, linear, sequential, analytical processes associated with the left hemisphere, and spatial, relational, holistic processes associated with the right hemisphere. Many learning models and teaching strategies in educational psychology strongly favour the linear, analytical approaches to teaching and learning based on information processing models of human cognition.

The computer metaphor for both information storage and information processing is now being challenged by both cognitive psychologists (e.g. Hunt, 1982; Carello et al., 1984) and educationists such as Phillips (1983). For example, Carello et al. (1984) argue that the

computer metaphor assumes that 'simply because an algorithm can be written to simulate a given activity of an organism, it does not necessarily follow that the organism uses such an algorithm in performing the activity in question'. Similarly, Phillips (1983) argues that investigations of cognitive structures confound two distinct types of structure, namely, the logical structure of a discipline on one hand, and the cognitive structure that is built up by the learner on the other.

Williams (1983) suggests that the computer metaphor is more appropriately used in connection with logical, analytical processing and she proposes a kaleidoscope metaphor to describe non-logical, holistic processing:

The kaleidoscope simultaneously combines its parts to create a rich variety of patterns. It moves by leaps as the parts are reshuffled and reassembled in different relationships to each other. In the computer each step determines which steps may follow it, while in the kaleidoscope the parts may relate to each other in an almost infinite number of ways (Williams, 1983, p.4).

Creative thinking and learning

In this section I suggest that creative thinking and learning can arise from the interplay between analytical and holistic mental processes.

Kaha (1983) proposes the concept of 'synchronicity' as the sudden innovative combination of multiple thought processes (analytical and nonanalytical) that can result in insight or illumination:

If it is true that the human mind works simultaneously on multiple activities could it not be that at certain times, for whatever reason a synchronicity emerges? By synchronicity I wish to indicate a state of affairs in which the processes occurring mesh or blend in such a fashion as to alter, in unpredictable ways, the direction of consciousness (Kaha, 1983).

Further, if the individual is aware of only one thought process at any given moment he or she would not be able to consciously apprehend the workings of such a synchronicity. The product, in the form of insight or image or knowledge becomes conscious, while the precise way in which that information becomes conscious remains subliminal. However, while individuals cannot consciously catch themselves in the act of creating they can often sense or feel such a process: mystics call it ineffable, scientists react with eureka! artists with ah! and students with aha!

Analytical thinking, nonanalytical thinking, and some sort of synchronous interaction between the two offer a tentative explanation of the process of creative discovery or understanding.

However, neither scientific discovery nor learning about science take place in a cultural vacuum. From a cultural perspective it is possible for the creative scientist's efforts to result in invalid or redundant theories, and for the student's best attempts at constructing meaning to result in misunderstandings. Thus, the third phase in learning involves communication and verification of understandings. In many learning models this

process is seen largely as an individual, intellectual process of comparison of new learning with existing cognitive structure. While this is an important process, I suggest that verification through social means plays an important role in learning.

Social processes - 'Am I right?'

Many cognitive learning models stress the personal and individual nature of the learning process and perhaps this is a valid emphasis. However, philosophers of science (e.g. Hodson, 1985) identify a third stage in scientific research in which the scientist communicates his or her results to the scientific community - he/she submits findings to social scrutiny and seeks feedback from others who may see the work from a new or different perspective. This is essentially a social phase in scientific research which has a parallel in the learning process.

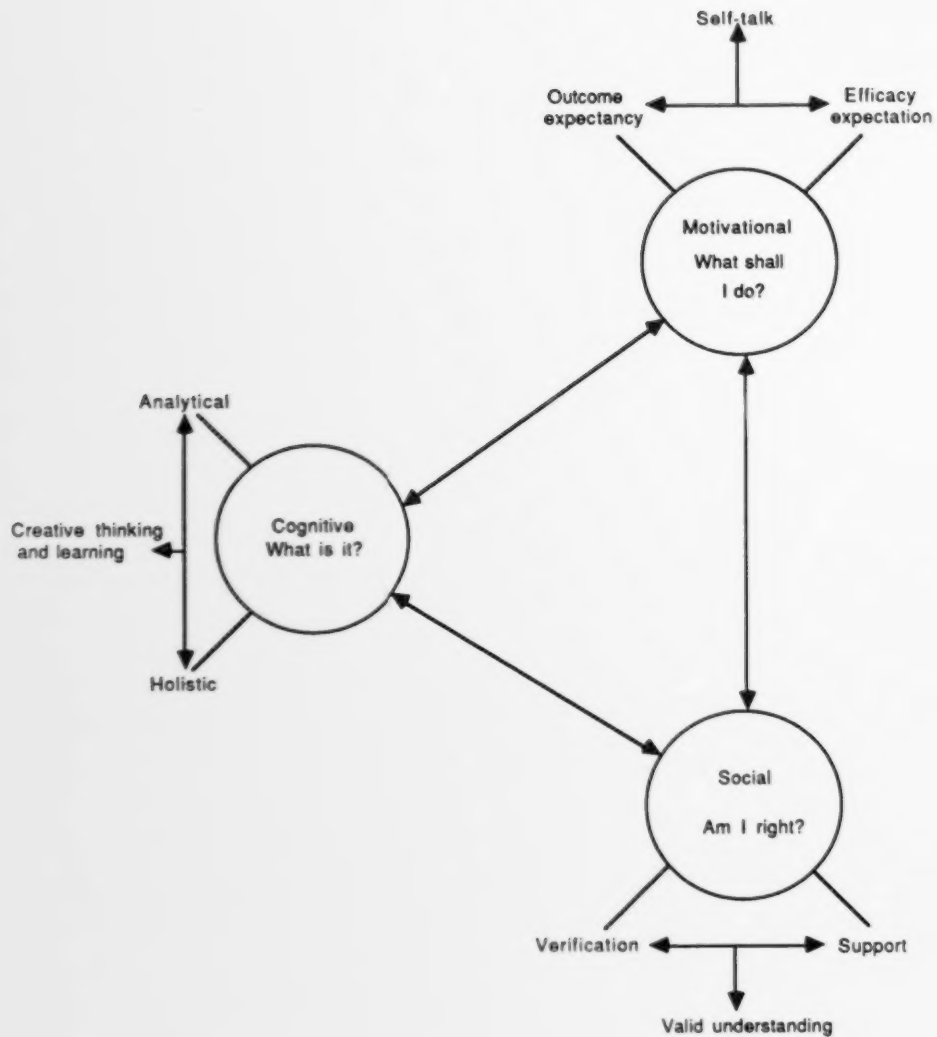
It is curious that the importance of communication within the scientific community and the sharing of ideas with colleagues is recognized in scientific research, but is frequently discouraged in the learning situation where students are told to 'think it out for themselves' and 'not to worry about what anyone else thinks'.

Psychologists identify a process of 'consensual validation' which people employ when attempting to understand ambiguous situations or information. Such situations must arise frequently in the science classroom, but why is the social verification of meaning-making attempts by students discouraged?

Making mistakes is not the unwanted end result of 'bad' learning, rather it is an essential part of meaningful learning. Studies in text comprehension (e.g. Owens et al., 1979) show that improved recall for episodes in a story is associated with a subject making more inferences that go beyond the information given. Experiments such as these suggest that when a learner is active in comprehending information, he or she will not only remember more information, but will also create inferences as a result of actively relating new information to existing understandings. These inferences may or may not be correct but it seems that they are essential to the process of active learning.

Thus, the social verification of created meanings becomes an essential part of the learning process. The way it is handled in the classroom has important implications for the learner in terms of feedback into the motivational and cognitive learning processes in the interactive learning triangle summarised in Figure 1. If a student is ridiculed, judged, blamed, or in other subtle but very effective ways 'punished' for his or her 'mistakes', the implications for future sense-making attempts by that individual are profound.

FIGURE 1



Some aspects of the learning process

CONCLUSION

Making sense of the world - including the world of school learning - involves making connections between new and existing experiences. Whether this process is called the construction (Piaget, 1929), the generation (Osborne & Wittrock, 1985) or the creation of meaning, the relation of new experiences to existing understandings, images, experiences, and feelings are essential to the process of learning with understanding.

For many years cognitive psychology has focused on the making of logical, sequential, highly structured connections. However, the computer metaphor for human information processing and storage is now being questioned and cognitive psychologists are beginning to explore the new 'unexplorable' - parallel, holistic, divergent, creative mental processes.

In addition, this paper proposes a model of the learning process in terms of reciprocally interactive cognitive, affective, and social variables.

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Research In Science Education, 1986, 16, 11-20.

LEARNING STRATEGIES AND THE LEARNER'S APPROACH TO A PROBLEM SOLVING TASK

Gloria Dall'Alba

INTRODUCTION

In the research literature there is considerable evidence of individual differences in the ways in which learners perform particular learning tasks. What is the nature of the differences in performance?

The research that is reported here is part of a larger study exploring the nature of differences in performance in terms of learning strategies and quality of learning outcomes. The purpose of the larger study is to explore the nature of the relation between particular strategies or patterns of strategy application and the learning outcomes. In this paper data are presented about the differences in performance of several learners on a problem solving task. The learning strategies which the learners applied were monitored and the learning outcomes were assessed with reference to the requirements of the task. The relation between the strategies and outcomes for the problem solving task is discussed.

A group of secondary science students aged between 13 and 15 years engaged in a problem solving activity. The learners were provided with apparatus including three types of sticky tape (See Figure 1). They were required to answer the question, 'Which tape sticks most strongly to the board?' (Refer to Box 1). During the activity the learners were encouraged to 'think aloud' and each interview was audio-taped. The interview transcripts were used in the identification of learning strategies. During the problem solving activity, the learners were instructed to write their results clearly. On completion of the problem solving activity they were asked:

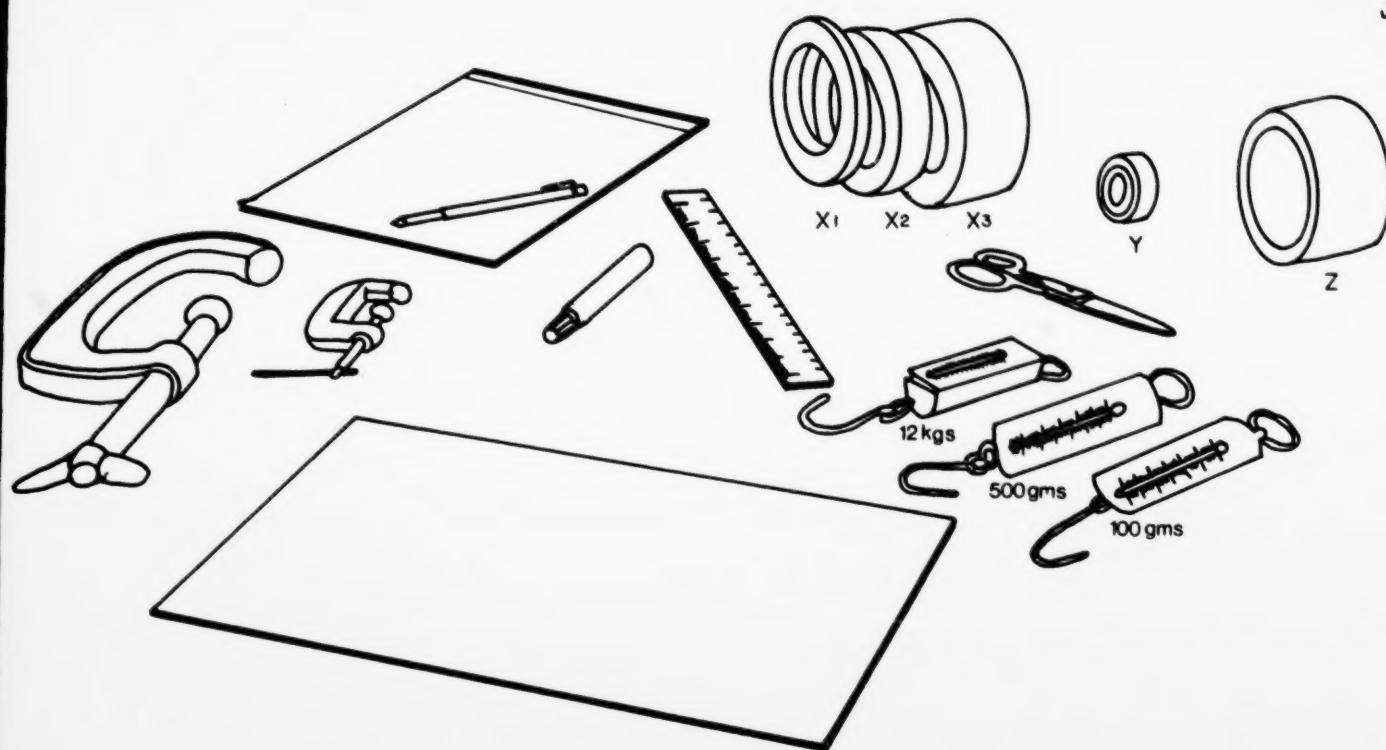
What was the problem you were asked to solve?

How did you solve the problem?

What did you find out?

The learners' responses to these questions, in conjunction with their problem solving performance, provided data on their interpretation of the problem, method of solution, and learning outcomes for this activity.

FIGURE 1



TASK ANALYSIS

The problem solving task was analysed closely by the author/interviewer to make explicit its nature and requirements. The interview transcripts for the activity were used in the analysis of the task. This means that the task analysis was based on a rational examination of the requirements of the task and on actual performance on the task. Following the task analysis, the performance of each learner was examined in relation to the nature and requirements of the task. This permitted a systematic assessment of the learners' performance.

The problem solving activity required that the learners (a) interpret the problem, (b) design a problem solving method, including control of the length of the tapes, sticking the tapes to the board, and measuring the strength with which each tape stuck to the board, (c) implement the method, (d) record the results, and (e) interpret those results.

BOX 1

INSTRUCTIONS FOR PROBLEM SOLVING ACTIVITY

There are lots of different kinds of sticky tape sold in the shops. Each manufacturer claims that their tape is best.
 You have been given three different kinds of tape labelled X,Y,Z.
 This is what you have to find out:
WHICH TAPE STICKS MOST STRONGLY TO THE BOARD?
 You can use any of the things in the box.
 Choose whatever you need to answer the question.
 Then clearly write down your results so that another person can understand what you have found out.

(Adapted from APU at 15, 1983)

I've typed the instructions on a card in case you want to remind yourself sometime about what you have to do.

IDENTIFYING THE LEARNING STRATEGIES

Data about the learners' method of solution and strategies were obtained using the 'think aloud' technique, written observations by the interviewer, and the selection by the learners of those descriptors applicable to themselves from a checklist of statements indicative of learning strategies (Refer to Box 2). The checklist is based on Baird's (1984) Tentative Classification Scheme for Some Evaluation Strategies Involved in Learning Written Information and on his Question-Asking Checklist.

In this study the learners' strategies were monitored at the level of the specific steps taken in performing the task. The strategies of interest in the study were those which Baird (1984) termed Evaluation Strategies. He defined them as those strategies 'which

BOX 2

PROBLEM SOLVING CHECKLIST

Topic

1. I thought about what the activity was all about.
2. I thought about other things I know about sticking or sticky tape.
3. It made me think about things I've seen and done.
4. I thought about whether I was interested in this sort of problem.

Detail

5. I realised how I was doing the activity (for example, carefully or in a casual way).
6. I looked for the important ideas.
7. I thought about whether I understood what I was doing.
8. If I didn't understand I did something about it.
9. I remembered other things that helped me to understand.
10. I had some questions about the activity that I did not ask.

Task

11. I thought about whether I understood what I was asked to do.
12. I thought about whether I was given enough information for the activity.
13. I thought about how I could use the equipment.
14. I planned what I would have to do.

Approach

15. I thought about how long it would take.
16. I thought about how hard it would be.
17. I thought about other ways of doing the activity.
18. I thought about why I was doing the activity.
19. I thought about whether I wanted to do this activity.
20. I thought about what I would get from the activity.
21. I thought about how I would use the result.
22. I thought about whether I would be able to do what I was asked to do.

Change in Knowledge

23. I thought about how the result compared with what I expected.
24. Some of my ideas were changed.
25. I thought about whether the result made sense to me.
26. I thought about whether the result seemed correct.

Increase Understanding

27. I thought about what might happen if something were changed. (For example, What if...?; What about...?)

Progress

28. I thought about how I was going with the activity.
29. I thought about what I should do next.
30. I thought about whether I was doing the activity in the best way.

Completion

31. I thought about whether I had done enough to stop.
32. When I had finished I thought about whether I understood it all.
33. I thought about what I would need to do to understand it all.
34. I thought about whether I had answered the question or finished the activity.

Future Use of Knowledge

35. I thought about how I could make sure I remembered how to solve this sort of problem.
36. I thought about how I could make use of what I'd learned in future.

permit monitoring of learner-and task-based variables, and learning progress' (p.127). For example, in solving a given problem a learner might (a) formulate a solution method, and (b) while implementing it, decide whether it is likely to lead to a successful solution. Baird's Tentative Classification Scheme for Some Evaluation Strategies Involved in Learning Written Information provided the focus for the identification of the strategies. Decisions about what constituted evidence of Evaluation Strategies were made with reference to Baird's scheme. -

INTERPRETING INDIVIDUAL DIFFERENCES IN STRATEGY APPLICATION

In an earlier paper (Dall'Alba & Northfield, 1984) the strategies which were applied by one learner, Gary, on the problem solving task were discussed and compared with those of other learners. The discussion primarily dealt with the frequency of occurrence of particular types of strategies. There was evidence of individual differences among the learners with respect to strategy application. For example, Gary formulated and carried out a single plan of action. Unlike another learner, he did not consider alternative methods.

Although supplying evidence of individual differences, the earlier paper failed to provide an integrated account of strategy application. It will be argued, in this paper, that the pattern of strategy application for the problem solving task becomes meaningful when interpreted in relation to the way in which the learner engaged in the task. With reference to the problem solving activity, this means that the strategies should be interpreted in relation to the way(s) in which the learner attempted to solve the problem. For example, to report that a learner attempted to establish the meaning of a given problem is much less illuminating than displaying how he confused sticking strongly to the board with strength of the tape. By adopting this holistic research approach, the relevance and effectiveness of single strategies or clusters of strategies is more likely to become evident (Refer to Marton in Schmeck, in press, for further discussion of this issue). Furthermore, the pattern of strategy application was found to be most meaningful when interpreted within the overarching framework of the learners' approach to the task.

APPROACH TO A TASK

Close examination of the strategies which were applied by the learners in the problem solving activity suggested that the successful solution of the problem was not dependent upon the strategies *per se*. For example, different strategies were applied by the two learners who successfully solved the problem. A more crucial factor appeared to be the learners' approach to the task, that is, the aspects of the learning material or the task on which the learners focused and the general way in which they set about learning

from the task. This conclusion provides support for the research of Marton and the Goteborg group (for example, Marton, 1975; Marton & Saljo, 1976; Svensson, 1977) and others (Laurillard, 1978, 1979; Ramsden, 1979, 1981) who advocate the importance of the approach to the task which the learners adopt.

Marton (1975) interviewed students about their experience of learning when reading a passage of text. On the basis of the students' accounts, he distinguished between 'surface' and 'deep' approaches. The learner who adopts a surface approach 'directs his attention to learning the text itself (the sign)' (Marton & Saljo, 1976, p.7), that is, the learner is concerned with reproducing the material. In contrast, the learner who adopts a deep approach 'is directed towards the intentional content of the learning material (what is signified)' (p.7), that is, the learner attempts to comprehend the author's message.

Marton subsequently expanded his description of the deep and surface approaches, following Laurillard (1978) and Ramsden's (1981) application of the dichotomy to other tasks and content areas. He listed subcategories of the two approaches (Refer to Box 3). Marton's (1983) description of the deep and surface approaches provided an overarching framework for interpreting the application of cognitive learning strategies in this study.

BOX 3

SUBCATEGORIES OF DEEP AND SURFACE APPROACHES

Subcategories of the deep approach

- (1) Focusing on what the 'text' is about (beyond)
 Focusing on the author's intention (what it was all about, the conclusion, the point of the article)
 Keeping the end point in mind throughout the solution process
 Having the phenomenon or the aspect of reality dealt with in the 'text' as the object of attention
- (2) Relating
 Relating the parts to each other or to the whole (within)
 Relating some parts of the 'text' to something outside it (between)
 Revealing the underlying structure of the 'text' (beneath)
- (3) Being active
 Finding out things (creative)
 Drawing one's own conclusions, making inferences (logical)
 Checking the logic of the author's line of argument (critical)

Subcategories of the surface approach

- (1) Focusing on the 'text'
 Try to memorise the material
 Concentrate only on procedures
 Hyperintention (concentrate on time limits, memorising, recall at subsequent test of retention)
 Lack of concentration on content
 - (2) Not relating
 Dealing with the parts in isolation, focusing on details
 - (3) Not reflecting
 Having a passive, constrained mind
- (From Marton, F. (1983), pp. 293 and 295).

STRATEGIES AND APPROACH TO THE PROBLEM SOLVING ACTIVITY

Of the ten learners who engaged in the problem solving activity, only two were successful in fulfilling all of the task requirements and solving the problem. The two successful learners, Helen and Norm, adopted a deep approach during their problem solving. For example, before deciding on a solution method, one of Helen's strategies was to consider a range of possible steps. She then excluded from her method those steps which she considered to be unnecessary to solving the problem:

- H. I thought of a few things but they didn't seem quite right.
 I. What sorts of ...things?
 H. Well, I thought of using the clamp to keep the board on the table, but I didn't need to do that.
 I. Mm.
 H. I thought of marking the sticky tape with a texta but I didn't need to do that either.
 I. How do you mean?
 H. Well just marking it ... It wasn't quite right so it didn't really matter.
 I. So it just sort of came into your head that maybe you could use it for that and then you realised that it wasn't going to be useful?
 H. Yeah.

When applying one strategy, the design of a solution method, Norm considered the individual steps in relation to the whole problem:

- N. Well I'm trying to find a way so I can judge um what type of way you'd take to lift these [tapes] off the board.
 I. Mm.
 N. I've taken the same length [for all three tapes], 10cm, here. Trying to think of a way to attach them [the tapes] to that [spring balance hook] so I can judge what weight it needs to get the whole tape off the board.

The above examples of strategies which were applied by Helen and Norm have been presented as part of these learners' attempts to solve a particular problem. The role of the strategies can be determined in relation to the way in which the learners attempted to solve the problem. The examples also illustrate how the learners' approach to the task provided an overarching framework for interpreting the strategy application. The significance of the strategies is related to the way in which the learners applied them in relation to the overall problem. That is, their significance is related to the deep approach which the two learners adopted.

The learners who adopted a surface approach tended to focus on individual steps and failed to relate them to the whole. For example, all of the strategies which were identified during Paul's problem solving were concerned with individual steps. His later

description of the way in which he had carried out the task confirmed that this was his focus:

I tried out to see which one, I thought this [100g spring balance] would be too loose ... I tried it and it was too loose. So I used this one [12kg spring balance] and it was just maybe too strong because we only got down to the one and um one kilojoule that was [pause] and then I got the sticky tape and the masking tape, not the masking tape the clear tape, and placed it over the hook and I got the board down with the G [clamp] and held it down to the table, held the sticky tape over the hook and [pause] then I thought, 'Should I pull it quickly and see how far I can get it down or should I pull it slowly and see what happens?' So I did it sort of slowly ... and whatever it got down to I wrote down and did the same with the masking tape and cut up the binding tape to the right size and did the same thing and found out what would happen.

In some instances, by concentrating on procedures, the learners deviated from the given problem. They appeared to lose sight of the way in which the procedures related to the solution of the problem. For example, Laura deviated from the problem by omitting the requirement that the tapes were to be tested against the surface of the board:

- L. Just say the handle fell off a cricket bat or something. You could tape it back and then, say, hit with it and see which one [that is, which tape], you know, sort of
- L. Holds best.
- L. Yeah.

None of the learners who adopted a surface approach was successful in meeting all the requirements of the task. In retrospect, this is not surprising. The task was an open one, in which the learners were required to formulate their own solution method. Concentration on procedures with a failure to keep in mind the end point would be unlikely to lead to success.

Examples have been given of successful learners who adopted a deep approach and unsuccessful learners who adopted a surface approach. To suggest that the data were completely polarised would be misleading. Outside these two groups were three learners who were unsuccessful but adopted a deep approach.

The first of these learners, Stan, tried two methods of solving the problem. In both methods he controlled the length of the tapes, stuck them to the board, and attempted to measure the strength with which they stuck, as required (Refer to Task Analysis). He also recorded and interpreted his results, expressing reservations about them. His lack of success was due to difficulties which he experienced in the measurement, rather than due to inadequacy in the methods themselves. In the subsequent discussion, Stan reported that he was conscious of a time pressure. (In an earlier interview with each learner, the interviewer had indicated that the tasks might take up to one hour. Stan treated this as a time limit.) He felt that the time pressure had affected his ability to overcome the difficulties he had experienced. As with Stan, the other two learners, Kay and Owen, were

aware of the need to measure the strength with which the tapes stuck to the board. However, they failed to completely satisfy this requirement. In addition, they both displayed some lack of clarity in their interpretation of the problem.

In summary, none of the learners who adopted a surface approach was successful in fulfilling all the requirements of the task. Two learners who adopted a deep approach were successful. The remaining three learners who adopted a deep approach were only partially successful. Success on the task appeared to be more strongly linked to the learner's approach to the task than to the strategies per se.

STRATEGIES, APPROACHES AND OUTCOMES

Earlier studies have provided evidence of the relation between learning approach and outcomes. How does the examination of the learners' strategies illuminate the relation between approach to the task and learning outcomes? First, determining what approach the learners adopted to a task provides some information about what the learners did while engaging in the task. However, more detailed information about the strategies which were applied in relation to how the learners carried out a task provides a more complete picture of what is meant by a deep or surface approach. (Such information would be useful in remediation.) The more complete picture of the learners' approach can then be used to inform the relation between approach and outcome.

Second, determining that learners adopted a particular approach overlooks the individual differences in the ways in which they completed the task. For example, Helen and Norm both adopted a deep approach but differed in the way in which they set about solving the problem. Helen re-read the instructions prior to beginning. She looked at the apparatus and considered how she might use the individual items, then excluded the unnecessary ones. Norm planned a general procedure prior to looking at the apparatus. His procedure was based upon his recall of a television program which dealt with a similar problem. After planning the general procedure, he planned how he could utilise some of the apparatus which was provided. Hence, although adopting the same approach to a task, learners may carry it out in distinctly different ways. The purpose of this research, namely, to explore the nature of differences in learners' performance, therefore, is better served by information about learners' strategies than simply about their approach to the task.

SUMMARY

In this paper data were presented about the differences in performance of several learners on a problem solving task. The nature of these differences was explored in terms of the learners' strategies and approach to the task. It was argued that the pattern of

strategy application should be interpreted in relation to the way in which the learner engaged in the task. Furthermore, the pattern of strategy application was found to be most meaningful when interpreted within the framework of the learners' approach to the task. Success on the task appeared to be more strongly linked to the learners' approach than to the strategies *per se*.

This paper has provided further insight into what is meant by a deep and surface approach to a task. Evidence has been presented which shows that the learners' approach may be implemented in practice in different ways. It is hoped that the paper will stimulate many questions relating to learning on other tasks and in different contexts. For example, do learners have a characteristic learning approach? Does their approach vary according to the task or context? What factors influence the learning approach which is adopted? What implications does the notion of approach to learning have for classroom teaching?

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Research In Science Education, 1986, 16, 21-30.

CASE STUDIES OF TEACHING PROBLEM SOLVING

Kam-Wah Lee

INTRODUCTION

The development in students of the ability to solve problems is a current interest and concern in education in general and in science education more particularly. The development of effective problem solving instruction is now receiving attention from many researchers who work in the area of problem solving (Reif, Larkin & Brackett, 1976; Reif, 1983; Bascones & Novak, 1985; Woods, 1985).

A number of case studies were undertaken by the author to examine the teaching and learning of problem solving in electrochemistry, using a naturalistic approach to the classroom situation. The studies have enabled the researcher to study experts and novices in action. Through the case studies, it is possible to identify the teachers' behaviour in teaching problem solving in electrochemistry and to infer things about the students' experiences of learning about solving problems in electrochemistry in their chemistry classrooms.

These data were used to focus on the issue of teaching problem solving by analyzing them in relation to (1) the learning experiences the students received through their teaching, (2) the cognitive variables that are important in problem solving, and (3) the strategies experts and novices use in problem solving. This paper is the third study (Study III) of the overall study which relates to variables (Study I), strategies (Study II), and teaching and learning of problem solving. The two earlier studies had established the role of the cognitive variables in problem solving and the sorts of strategies that are used by the experts and novices in solving electrochemistry problems.

It was found from the first study that six cognitive variables i.e. Non-Specific but Relevant Knowledge (NSRK), Specific Knowledge (SK), Problem Translating Skill (PTS), Prior Problem Solving Experience (PPSE), Idea Association (IA) and Concept Relatedness (CR) are important predictors of the problem solving performances (Lee, 1985). They do, however, have different degrees of influence on the problem solving performance for different types of problems (i.e. types as indicated by familiarity).

In the second earlier study, 136 protocols of the problem solving by the teachers and the students were analysed in terms of a number of processes that occur in their solution. A General Strategy of Problem Solving (see Box 1) was identified (Lee, 1986).

BOX 1

PROCESSES IN THE GENERAL STRATEGY OF PROBLEM SOLVING

1. Stage 1 - Translation of the problem statement
 - (a) Comprehending the whole problem
 - (b) Translating the parts of the problem statement so that they have meaning
 - (c) Setting goal(s) or subgoal(s)
2. Stage 2 - Moves towards a solution
 - (a) Selecting information from the translation
 - (b) Retrieving 'rule(s)' or 'fact(s)' from memory
 - (c) Achieving goal(s) and/or subgoal(s) (by explicit or implicit linking of Processes 2a and 2b)
 - (d) Checking the path(s) of the solution or the answer(s)

Three categories of patterns of problem solving strategy emerged as Pattern 1, Pattern 2 and Others when the sequence of occurrence of these processes in the General Strategy of Problem Solving was used as the reference for coding these 136 protocols (Lee, 1986).

Pattern 1 has the processes of Stage 1 (Translation of the Problem Statement) occurring first and then the processes of Stage 2 (Moves towards the Solution) occurring later in the protocol (see Fig. 1).

FIGURE 1

Stage sequence of Pattern 1

Stage 1 → Stage 2

Pattern 2 has two (or more than two) repeated Pattern 1 problem solving strategy for different subproblems (see Fig. 2).

FIGURE 2

Stage sequence of Pattern 2

Subproblem 1 Subproblem 2 Subproblem 3
 Stage 1 → Stage 2 → Stage 1 → Stage 2 → Stage 1 → Stage 2

Others is the set of strategies which are neither Pattern 1 nor Pattern 2 but in which irregular sequences of the processes involved in these stages appear.

DATA COLLECTION

Four teachers who had been involved in the earlier studies also participated in Study III, the case studies of teaching problem solving. They were from four different schools (1 boys, 1 girls and 2 co-ed). The case studies involved classroom observation and recording by the researcher of these teachers, while they were teaching the topic of electrochemistry at H.S.C. levels (Year 12). The teachers were clearly told that the purpose of these visits to their classrooms was to observe their teaching of electrochemistry topics and particularly their teaching of problem solving. The visits were arranged by the teachers according to their teaching schedules. Among the four cases, the number of visits ranged from three to five lessons. For each lesson, the researcher sat at the back of the classroom to observe the activities occurring during the teaching. The blackboard and/or overhead presentations and the teachers' verbal instructions included their dialogues with the students were written down by the researcher. The teachers' oral teachings were taped during the lessons with the permission of the teachers. The totality of these data will be referred to as the teaching record of each case.

DATA ANALYSIS

These data, i.e. the teaching records, were qualitatively explored and analyzed with the intention of answering the following three questions:

1. What are the potential learners' experiences in classroom learning of problem solving?
2. How does the teachers' teaching behaviour in teaching problem solving relate to the findings of the earlier study on the role of cognitive variables in problem solving?
3. How does the teachers' teaching behaviour in teaching problem solving relate to the findings of the earlier study concerning the sorts of strategies used by experts and novices in solving electrochemistry problem?

Because the data of the cases are essentially the words, actions, and instructions of teachers to their students in chemistry classrooms, they can in a reverse sense, be seen as providing a series of learning opportunities or experiences for the students who are present in these classrooms. It is of course unlikely that each student present in the classroom would have responded equally to all these opportunities and hence participated equally in

the learning experiences they provide. Without parallel data from each student about how they experienced these teaching situations, it is not possible to identify the individual learning experiences for comparison or matching. Nevertheless, a range of the potential learning experiences that are available to the students in each class can be inferred from the teaching record of each of the cases. It is this basic inference that is made in each of the three different approaches to the analysis of the cases that are described in this paper. Learning experiences that are not identified in this way are thus not available to the students from their classroom instruction although they may of course be acquired by some of them through extra-classroom events.

There are, of course, a number of other sources of learning experiences about electrochemistry for these students. There is their interaction with textbooks, their mutual interactions, their homework, practical work, other subjects involving problem solving like physics, personal work with the teacher, etc.

For the purpose of this study we are, however, assuming that the range of learning experiences identified from the records of the cases does establish significant boundaries to the learning that is available to the students in each case.

To answer the first question above, an "open" approach to the analysis of the teaching records is used to gain some comparative insight into the teaching strategies that were employed by the teachers in these four cases. The answers for the second and third questions were intended to complement the earlier statistical study of variables in problem solving (Study I), and the study of teachers' and students' strategies (Study II). Accordingly the analyses used to answer questions 2 and 3 have involved the relevant variables and characteristics of the strategies, that had already been established in these two earlier studies.

RESULTS AND DISCUSSION

1. Strategies of teaching problem solving and the range of learners' experiences

The electrochemical topics involved in the four teachers' teaching schedules are (1) General redox problem, (2) Galvanic cells, (3) Standard electrode potential (E°), (4) Application of E° to the determination of a redox reaction, and (5) Electrolysis.

The case studies focussed on the first four topics which cover all the background knowledge for the types of problems chosen for this research investigation. This means the teaching of electrolysis (teaching area 5) was excluded from these case studies.

There were altogether 12 lessons in the four cases. The distribution of the recorded lessons among the four teachers are: Tr. 1 : 1, Tr. 5: 3, Tr. 7 : 4, and Tr. 10 : 4. Tr. 1 is included, despite the fact that only one of this lessons provided an analysable teaching

record. His other lessons for the topics were practice periods in which the students were attempting to solve electrochemistry problems and in which some of them received additional individual instruction from him.

The teaching records were read over and listened to repeatedly by the researcher. One obvious way to consider the teaching in each lesson is in terms of the sub-topics of electrochemical content being taught. Such a sub-topic could be an electrochemical concept, a set of concepts, or an example of a problem involving these concepts. Each piece of teaching in the records that relates to such a sub-topic was counted as a session of teaching. In this way the records contain 35 sessions by the four teachers overall. This breakdown of the lessons into sessions defined by an electrochemical sub-topic does not take into account the time devoted to each of these various sub-topics.

From the teaching records (written and taped) of the 35 sessions, three distinguishable approaches for teaching problem solving emerged (see below). In classifying these three approaches, we are not assuming the intent the teachers may have for teaching in this way. For example a teacher may believe he is teaching a strategy when we classify his teaching as "demonstrating a solution to a problem". The teaching in a session is only classified as "teaching a strategy" if it is an overt and explicit discussion by the teachers about the procedure he was using and the reasons for it as a strategy of problem solving.

a. Types of approach for teaching problem solving

i. Teaching Approach 1

Teacher concentrates on communicating the chemical background knowledge that is required in the solving of the problems.

ii. Teaching Approach 2

Teacher concentrates on communicating the demonstration of solving the problems.

iii. Teaching Approach 3

Teacher concentrates on communicating one strategy to be employed when one is confronted by a problem situation.

b. Discussion on teaching strategies and learners' potential experiences

The potential range of the learners' experiences in the reverse sense of these teaching approaches can then be briefly described as follows:

- (1) Having the relevant knowledge for problem solving identified.
- (2) Witnessing a demonstrated solution of a problem.
- (3) Hearing an explanation of one strategy for solving a particular problem.

The order of these three types of experiences in terms of the extent of exposure towards a particular teaching approach in the four individual classes are indicated in Table 1.

The potential range of the learners' experiences across the four cases was generally centred around seeing and hearing demonstrations of the solution of electrochemistry problems. The students were not exposed to a variety of ways to think about solving electrochemistry problems or to any overt discussion of various strategies that might or could be used in solving the same or different types of problems.

Even, the students in the classroom of Tr. 1, who were offered a range of learning experiences 60% of which was hearing about the strategy for a given problem explained (20% was having the relevant knowledge identified and 20% was seeing and hearing a particular problem being solved), did not experience a discussion of various strategies.

TABLE 1

Order of learners' potential experiences in four cases

Class of	Having the relevant knowledge for problem solving identified	Witnessing a demonstrated solution of a problem	Hearing an explanation of a strategy for a particular problem
Tr.1	2	2 *	1 *
Tr.5	2	1 *	2
Tr.7	3	1 *	2
Tr.10	2	1	3

* "1" indicates the highest order in the frequency of potential experiences.

2. Teaching problem solving and cognitive variables of problem solving

a. Identification of the six cognitive variables in the teaching strategies

Using the definitions of the variables in the context of teaching (see Notes on page 30) as guidelines, the teaching records of the four cases were next examined for examples of teaching behaviour that related to these six variables. A variable is regarded as present in a teaching session if it is clearly identified once in the record. Again, time spent on variable or frequency in a session have not been used as weightings. Such weightings could, of course, be included in this sort of analysis but initially it was more important to see whether the present simpler analysis would lead to useful findings.

If the teaching of a particular variable (e.g. PTS) occurred in a half or more than a half of the total number of sessions, the researcher, for the purpose of this discussion, considered that variable to be reasonably emphasized during the teaching.

b. Discussion on teaching problem solving variables

Table 2 gives the total frequencies of the teaching counterparts to the variables in the four cases.

TABLE 2

Total frequency occurrence of the teaching counterparts to
the problem solving variables in the 4 cases

Tr.	Total No. of Sessions	NSRK	SK	PTS	PPSE	IA	CR
1	3	2*	2*	1	2*	0	3*
5	9	5*	5*	3	3	0	2
7	11	6*	6*	7*	7*	3	1
10	12	7*	10*	4	8*	0	3

* Occurrence in at least half of the total number of sessions involved.

The extent to which the teachers included in their teaching counterparts to the six variables can be summarised as follows.

1. The variables NSRK and SK were reasonably emphasized by all the four teachers in the classrooms.
2. The variable PPSE was emphasized by 3 of the 4 teachers in the classrooms.
3. The variables PTS, IA and CR were not commonly communicated in at least 3 of the 4 cases. IA is the variable least taught. Three teachers did not involve this variable in their teaching.

The observation and analysis of the teaching behaviours of these four teachers shows that development in the students of the learners' variables NSRK, SK and PPSE could be expected since they were generally emphasized in the classrooms. However, the learning of what is implied by the variables PTS, IA and CR is unlikely since they were not emphasized in the teachers' presentations. For instance, the training of the skills of problem translation such as selecting the important information from the problem statements, interpreting the possible meanings of the statements and setting goals from the statements was hardly found in these four teachers' records.

These findings suggest that one way to develop and improve these teachers' teaching would be to include more emphasis on the missing variables since they have been shown to be important skills for problem solving.

It was also observed that the teaching of problem solving in general was more or less a "spoon-feeding" exercise during which the students were relatively passive. The teachers provided the facts or the solutions in most of the exemplary problems. The students were rarely given much opportunity throughout these sessions to be involved actively in practising even those learning variables that are included in the lessons, through responding to questions, or to mini-examples, being asked to try to solve aloud, etc.

3. Teaching problem solving and problem solving strategies

The problem solving behaviours that the four teachers communicated in their classrooms were analyzed in terms of the sequence of solution stages. This part of the study only analyzed the sessions in which the problems used by the teachers consisted of at least two subproblems. The teaching of this kind of problem was selected because an analysis in terms of patterns within the strategies of problem solving refers to sequences of the processes in Box 1 that manifest themselves in problems that consist of two or more subproblems. The results of these analyses were subsequently compared with the results found earlier so that the relations between the counterpart in the teaching of problem solving and the teachers' behaviour when they were solving problems in Study II could be compared.

a. Sequences of solution stages

The patterns of problem solving strategies that were communicated by the teachers in the teaching records were identified. The same guidelines and procedures as used in Study II were also used here.

The frequencies and the percentages of each pattern communicated by the individual teacher were worked out and are presented in Table 3. Again, if a particular pattern occurred in a half or more than a half of the total number of problems taught, the researcher considers that this pattern was used frequently in teaching and hence the learners were well exposed to it and likely to learn it.

TABLE 3

Comparison of percentages of teachers' patterns in two different situations

Tr.	Situation	No. of problems	Pattern 1	Pattern 2	Others
1	Teaching Protocol	2	50	0	50
		3	33	0	67
5	Teaching Protocol	6	67	0	33
		3	67	0	33
7	Teaching Protocol	10	70	20	10
		3	33	67	0
10	Teaching Protocol	7	71	0	29
		3	33	67	0

It is noticed that the four teachers frequently used a Pattern 1 type of strategy in their teaching. By contrast, a Pattern 2 strategy was communicated only by one of the

teachers (Tr. 7) and then again only in 2 of his 10 total problem events. An Others strategy (or so called "irregular strategy") was sometimes communicated by the teachers.

b. Discussion on the result in relation to the findings of Study II

The teachers did communicate Pattern 1 strategies frequently when they taught solving electrochemistry problems. However, from the analysis of their protocols in Study II it was found that some of these teachers used different strategies when they solved the same types of problems themselves. Table 3 also gives the percentages of each pattern that was used by the individual teachers in the (1) teaching situation and (2) protocol situation. Some differences between the choice of strategies in the two different situations are evident.

Two of the teachers behaved similarly (Tr.1 and Tr.5) in the use of strategies in the teaching and in the problem solving situations whereas the other two teachers behaved differently (Tr.7 and Tr.10). Some teachers thus appear to have a variety of strategies for problem solving but do not display this when they are teaching the same sorts of problems in their classes.

SUMMARY

Some important results that relate to classroom learning and teaching of problem solving emerge from these case studies. These are now summarized as follows.

In terms of the students' potential learning experiences of problem solving, it was found that the students were mainly witnessing their teachers' demonstrations of using rules or algorithms for solution to problems. Repeated practice of solving the sorts of problems that occur in examinations was also emphatically included as part of the learning experience. The students were not exposed to a range of strategies that could possibly be used to solve the same problems. There was no explicit teaching of important problem solving skills such as translation skills (comprehending, analyzing, interpreting, and defining a given problem) and linkage skills (concept relatedness between two concepts or using cues from the problem statements to associate ideas, concepts, diagrams, etc. from memory). When teachers solve problems they use, in general, several strategies to solve the same class of problems and they are very careful and explicit about translating problem statements, making relevant linkages and checking.

These absences in the teachers' teaching of problem solving (and hence in the students' range of learning experiences) are particularly interesting because they are part of the teachers' own repertoire of skills. Accordingly, it may not be too difficult to get teachers to include them in their teaching. This would mean that the students' range of learning experiences for problem solving would be very much strengthened.

Notes

The definitions of the six variables in the context of teaching are stated below:

1. Non-specific but Relevant Knowledge (NSRK)
Identifying and communicating the rules or facts which are generally related but not specific to the three electrochemistry problems that the students (and teachers) were asked to solve.
2. Specific Knowledge (SK)
Identifying and communicating the rules or facts which are directly related to or required for solving the three problems.
3. Problem Translating Skill (PTS)
Communicating or training the skills of comprehending, analyzing, interpreting and defining a given problem.
4. Prior Problem Solving Experience (PPSE)
Relating to prior experience in solving similar problems during the teaching.
5. Idea Association (IA)
Encouraging the association of ideas, concepts, words, diagrams or equations and particularly through the use of cues which occur in the statements of electrochemistry problems.
6. Concept Relatedness (CR)
Communicating the relationship between two concepts with the focus on the word association.

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Research In Science Education, 1986, 16, 31-39.

COMMON SENSE ANSWERS IN PHYSICS

Catherine Ameh

INTRODUCTION

In the numerous studies of children's ideas about scientific phenomena, concepts of electricity have been frequently probed (e.g. Osborne, 1981; Osborne and Gilbert, 1979; Russell, 1980; Shipstone, 1982). More recently, Butts (1985) investigated the concepts of electric current held by children in three countries. His work used the interview technique developed by Osborne and Gilbert (1979), and aimed to establish the extent of use by children of the four models for electric current in a simple D.C. circuit outlined by Osborne (1981, 1983). Osborne's four models are:

1. The scientist's "equal current model" in which the current is considered to be the same both before entering and after leaving the bulb.
2. A "diminishing current model" in which current is believed to travel around the circuit but to be 'used up' partially in producing light in the bulb.
3. A "clashing currents model" in which it is the clashing of currents coming from each pole of the battery that is thought to create the light in the bulb, and
4. An "extinction model" in which the current coming from the battery is believed to be used up in the production of light at the bulb, even though a return wire may be deemed necessary.

The purpose of the present study was to investigate aspects of the concepts of electric current held by science teachers and, in particular, to determine whether all four of Osborne's models are used by teachers.

SAMPLE

A total of 251 secondary school science teachers in Nigeria responded to a pencil and paper test which included four items about electric current. The test was based on the work of Osborne.

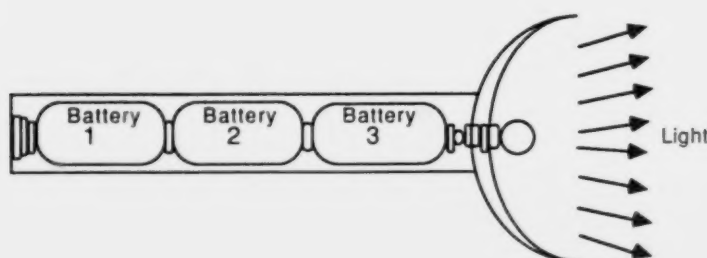
Interviews were subsequently conducted with 45 of the respondents. The teachers fell into one of four groups according to qualification: NCE (National Certificate of

Education - 3 years training after 0 level); B.Sc. only; NCE plus B.Sc., P.G.D.E. (B.Sc. plus Postgraduate Diploma in Education).

RESULTS

These are considered separately for each of the four questions. The question is reproduced in each case.

Question 1: A torch has three batteries in it, as shown in the diagram.



The torch is switched on and the lamp is glowing. Five students all have different ideas about the electric current through the batteries. Which one of the following ideas do you think is the best idea?

- (a) No. 1 will have the most current.
- (b) No. 2 will have the most current.
- (c) No. 3 will have the most current.
- (d) Nos. 1 and 3 will have more current than No. 2.
- (e) They will all have the same current.

Responses to Question 1 are shown in Table 1.

TABLE 1

	a	b	c	d	e	NR	Total
B.Sc.	0	1	11	2	57	8	N = 79
NCE/B.Sc.	0	0	2	2	10	3	N = 17
NCE	5	2	26	9	89	9	N = 140
PGDE	0	0	2	1	12	0	N = 15
Total	5	3	41	14	168	20	251

Option C Forty-one (16.33%) respondents - said battery No. 3 will have the most current: "No. 3 will have the most current. Looking at the torch, the batteries are arranged in series connection or arrangement and it means the movement of the current from one battery to the other until it goes to the tube, the nearest battery to the bulb, so that it will collect the current in one and two and combine it into 3 so that it will push it to the bulb so that the bulb can light".

"They will not have the same current, it's only when they are in parallel that they will supply the same current. If they are in series there is the probability that they have the same current but on certain conditions....."

"No. 3 will have the most current because it is very near to the bulb. No. 3 will have the most current because there is movement of current directed toward the end of the torch. They will accumulate in No. 3."

Option D Fourteen (5.57%) respondents said No. 1 and 3 batteries will have more current:

"No. 1 and 3 will have the most current, from childhood experience. When we arrange batteries we get the two strong ones and put them at the two extremities, but if you put them at the centre, the light doesn't function as it should.

Option E One hundred and sixty-eight (66.93%) respondents said they will all have the same current.

"All have the same because they all have the same potential energy. When you switch on the flow of electricity is to and fro, one will not give more than the other. All will have the same current.

"All the same, because the current is the flow of electrons, when the bulb lights an equal amount flow from the batteries because they are all connected in series so an equal amount of current is produced".

"Equal current because there is no indication that any of the batteries is having a higher voltage, so I presume they have equal voltage".

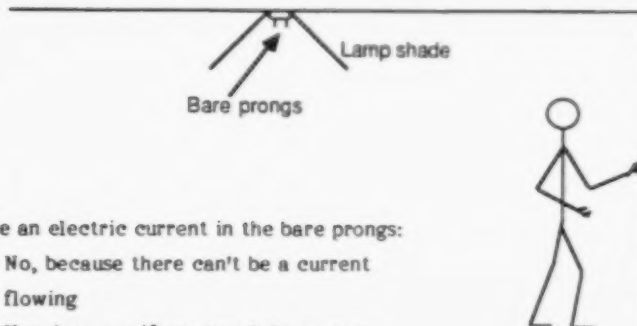
"Same because they are all connected together and they are generating the same current".

TABLE 2

	a	b	c	d	NR	N =
B.Sc.	6	20	29	15	9	N = 79
NCE/B.Sc	0	7	4	2	4	N = 17
NCE	23	48	48	14	7	N = 140
PGDE	1	5	6	3	0	N = 15
Total	30	80	87	34	20	251

Question 2:

This question is about an ordinary electric light which is fixed to the ceiling. The light bulb has been taken out but the switch on the wall is on.



Is there an electric current in the bare prongs:

- (a) No, because there can't be a current flowing
- (b) Yes, because if you touch it you get a shock
- (c) Yes, because if you put a bulb there it would glow
- (d) Yes, because the current would be going out from the prongs.

Responses to Question 2 are shown in Table 2.

Thirty (11.95%) were scientific in the options. Two hundred and eighteen (86.85%) were unscientific. Out of the 218, eighty (36.69%) said there is electric current in the bare prongs because

- . Yes, because if you touch it, you get a shock. (That shows the presence of electricity in the wire).
- . Yes, if you touch it, you get a shock. If there is no electric current, you will not get a shock.

Eighty-seven (39.90%) said yes, because if you put a bulb there it would glow.

- . Current is still there.
- . Yes, the bulb will glow as far as the switch is on.
- . Yes, there will still be current because when the switch is on, the circuit will still be complete.
- . There is electricity, use a bulb to test.
- . Yes, because if you put a bulb there it would glow.
- . Yes, current will still be flowing.
- . Yes, if you put it there will be light.

Question 3 A car battery has been fully charged but has not yet been placed in the car. It is sitting on the bench in the garage and is not connected up to anything. Is there an electric current in the battery?

Responses to Question 3 are shown in Table 3.

TABLE 3

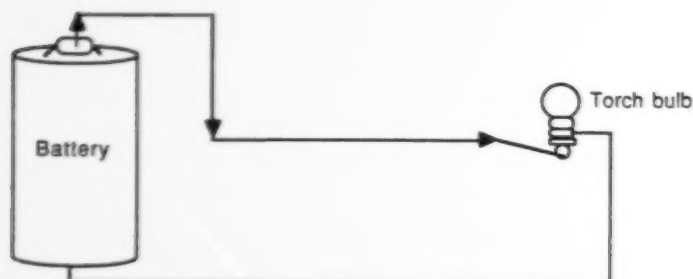
	Yes	No	NR	N =
B.Sc	32	22	25	N = 79
NCE/B.Sc	7	6	4	N = 17
NCE	74	45	21	N = 140
PGDE	8	5	2	N = 15
Total	121	78	52	251

One hundred and twenty-one (48.2%) said there will be electric current in a charged car battery which is not connected up to anything.

- There is a current in the battery.
- Yes, the battery has been charged so there is current.
- Yes, since it is charged, there should be current since it is not connected yet the current is just internal inside the battery.
- Yes, because it has been charged, the fact that it has not been fixed, means the current will remain there.
- Yes, because there is a positive and negative cathode and if you have to connect two wires there it will light a bulb.
- Yes, since it's fully charged, current is there.
- Yes, because it's a lead acid accumulator you have acid inside, there are electrodes inside so currents still flow.
- Yes, as it is not fixed in the car, if you just put two wires and join them together, it will show light that is sign of electric current.
- Yes, even if it's not in use because it has been charged.
- Yes, the current is within the cells although there are no cables.
- Yes, the current has been stored in the battery.
- Yes, because it is charged, the word charged is sufficient to confirm there is electric current.
- Yes, by charging the battery, we reactivate it, i.e. producing current in the battery.
- Yes, whether it is really connected or not it should still have currents.

Question 4: Models of electric current

A battery is connected to a torch bulb as shown



The bulb is glowing and the electric current in the wire marked A is shown by the arrow pointing from the battery to the bulb.

- a) Which of the following is the best sentence about electric current in Wire B?
- There is no electric current in wire B.
 - There is some electric current in wire B but less than in wire A.
 - There is the same electric current in wire B as in wire A.
 - There is more electric current in wire B than in wire A.
- b) Which of the following is the best sentence about the direction of electric current in wire B?
- The current has not direction as there is no current.
 - The current is in the direction from the battery to the bulb.
 - The current is in the direction from the bulb to the battery.

Responses to Question 4(a) are shown in Table 4.

TABLE 4

	a	b	c	d	NR
B.Sc	6	18	42	3	10
NCE/B.Sc	3	1	10	-	3
NCE	22	24	85	2	7
PGDE	0	0	14	1	0
Total	31	43	151	6	20

Responses to Question 4(b) are shown in Table 5.

TABLE 5

	a	b	c	NR
B.Sc	8	22	37	12
NCE/B.Sc	2	5	7	3
NCE	17	51	64	8
PGDE	0	5	10	0
Total	27	83	118	23

From Questions 4(a) and 4(b) four models of electric current were identified.

MODEL I

"Equal current Model" - 151 respondents (60.12%)

- * Same because they are all in the battery. They are being used equally, they all touch each other so the current should be equal.

"Diminished Current Model" - 43 respondents (17.13%)

- * When you have a current there is a circuit. The current generated will travel from 'A' through the torch bulb to 'B' and back to the battery. The current coming from wire 'A' due to potential difference hence there is some electric current but less than that of 'A' because 'A' generates the electric current, goes through the bulb. Whatever is left from the torch bulb after it is glowed is the one that goes through 'B' back to the battery which is definitely less than that of 'A'. Its less because at this point from the battery, the bulb uses some amount which is less than that, the bulb has used up.
- * There is some electric current in 'B' but less than in 'A'. The current now going out into the bulb will be used up to light the resistant wire which collects the current, which resists the movement of the current, which use some of it to light, by the time it leaves the bulb and goes into the battery, I expect that some of it has been used up.
- * There is a drop partly in 'B' because there must be potential difference before the current could flow. So the lighting has already consumed some current, so moving from +ve to -ve it means the potential at 'A' is better than at 'B'.
- * 'B' would be less than 'A' because some of the current has been converted into energy used by the bulb.
- * 'A' will have more current than 'B' because 'A' will start the current then it will come down to wire 'B'.

- There is electric current in 'B' but less than in 'A' because since the light is coming out from here, the one from 'A' is greater i.e. why it is showing light so I feel 'A' is stronger than 'B'. The light has reduced the amount of current.
- There is electric current in wire 'B' but less because wire 'B' is conducting electric charges that have already been burnt in the bulb.

"Clashing Current Model" - 83 respondents (33.06%)

- From the battery to the bulb because the current is flowing from the battery.
- The current will be flowing from the battery to the bulb because the top part is the positive while the bottom is the negative. Before any light will glow the positive and negative charges must meet at a particular point in the bulb— In the bulb there is the positive and negative terminal so the current will be flowing to the bulb to make the glow, not flowing from the bulb because the bulb does not contain anything like battery from where the current is coming.
- Battery to the bulb because the battery is the main source of energy.
- Battery to the bulb, the bulb cannot produce any current.
- Battery to the bulb because without the battery, the bulb will not work.
- Battery to the bulb because it is normal that it's the battery that is making the light to come.
- Battery to the bulb, the battery is charged. When it is charged, when the circuit is completed, definitely the current will be flowing from the battery.
- Battery to the bulb, the bulb in itself doesn't contain any current, for the bulb to light even if 'A' is connected to the bulb, it will not light until it is connected to 'B'.
- Battery to the bulb, the current should come from the power.

"Extinction Model" - 31 respondents (12.35%)

- Yes, some current in 'B' but less than 'A' because 'B' is earthwire, so it has no current.
- No electric current in wire 'B' because there is no indication that there is.
- No electric current in wire 'B' since it's the movement of the ions coming out. The positive end will actually gain electrons, the negative end will donate electrons, so there will be no electricity in 'B'.
- There is no electric current in wire 'B' because it's not attached to the top of the battery, I don't see how the current can be drawn from the bottom.

Responses to 4(a) and 4(b) are summarized in Table 6.

DISCUSSION

Based on Osborne's Models, one hundred and fifty-one (60.15%) of the total respondents favour "Equal Current", forty-three (17.13%), "Diminishing Current", eighty-

three (33.06%), "Clashing Current" and thirty-one (12.35%), "Extinction Current".

The confusion about nature, direction and magnitude of current flow extends to other situations (Questions 1-3) and the finding does not show that teachers are superior to the students they teach. Although these results were obtained from samples in Nigeria, a pencil and paper test administered to a group of trainee secondary school science teachers in Monash shows a similar pattern, as follows:

Equal	Diminishing	Clashing	Extinction
76.19%	16.16%	7.14%	4.76%

There is therefore a strong suspicion that this type of "Common Sense" response is universal. Butts (1985) has demonstrated that children from three different countries showed this pattern of response. It is becoming obvious that teachers are often not superior in science concepts to their students.

TABLE 6
Table of Models of Electric Current

Models	B.Sc	NCE/B.Sc	NCE	PGDE	Total
1. Equal Current	42	10	85	14	151
2. Diminishing Current	18	1	24	0	43
3. Clashing Current	22	5	51	5	83
4. Extinction	6	3	22	0	31

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Research In Science Education, 1986, 16, 40-48.

IDENTIFICATION OF SECONDARY STUDENTS' MISCONCEPTIONS
OF COVALENT BONDING AND STRUCTURE CONCEPTS USING
A DIAGNOSTIC INSTRUMENT

Ray Peterson, David Treagust and Patrick Garnett

INTRODUCTION

Over the past decade considerable interest has been shown in studies relating to students' understanding and misunderstanding of science phenomena either prior to or following instruction. It is now evident that students often have views of science concepts which differ from those generally accepted by the scientific community. These alternative student views have been labelled, among other terms, as "children's science" (Gilbert, Osborne & Fensham, 1982; Osborne, Bell & Gilbert, 1983) or "alternative frameworks" (Driver & Easley, 1978).

Various approaches have been used to identify students' understanding and misconceptions of science phenomena. Of these approaches, interview methodologies have acquired strong support as a viable approach (Osborne & Gilbert, 1980; Watts, 1981). Although interviews with students have been successful in ascertaining students' understanding of science phenomena the interview methodology has possible limitations if it is to be used by classroom teachers. This is in part due to the teacher time required to administer individual interviews and the fact that many science teachers are not trained to conduct interviews, to record and transcribe interview data or to interpret findings (Fensham, Garrard & West, 1981).

To assist the classroom teacher in identifying misconceptions of science phenomena, it is necessary to develop methodologies which can be readily used by teachers in their classroom environments. One method which would enable chemistry teachers to measure students' understanding of concepts and identify misconceptions is to have an easily administered and scored pencil and paper instrument based on multiple choice items. While multiple choice items have previously been used to measure students' understanding of science subject matter, test items have generally evaluated subject content knowledge (see for example, Duncan & Johnstone, 1973; Driscoll, 1974) and have not considered the

students' reasoning behind their content choices. Tamir (1971) and more recently Treagust (1986) have recommended the use of alternative multiple choice items to questions specifically based on student reasoning which include known misconceptions. This methodology has been utilised by Peterson (1986) to examine secondary students' understanding of covalent bonding and structure.

PURPOSE

The purpose of this paper is to

- describe the development of a test instrument to diagnose senior secondary students' understanding of the topic covalent bonding and structure.
- highlight some common misconceptions identified through the administration of the diagnostic test instrument.

METHOD AND PROCEDURES

Instrument Development

Prior to the development of test items, it was necessary to establish the content boundaries for the topic, covalent bonding and structure. These content boundaries were defined through a validated concept map and a list of 33 propositional knowledge statements. Subsequently, test items were prepared on identified areas of conceptual difficulty and students' misconceptions which were observed by unstructured interviews, analyses of student drawn concept maps and open-ended pencil and paper measures.

Items for the test instrument were based on a two-tier multiple choice format. The first tier of each item consists of a content question having two, three or four choices; the second part of each item contains four possible reasons for the answer given in the first tier. Included in these reasons are the correct answer and three identified non-acceptable reasons involving misconceptions. The non-acceptable reasons for each item were based on students' alternative views of the concepts and propositions identified by interviews and by administering an open response version of the pencil and paper test instrument. In this version, students were given the same content component of the item but were required to supply a reason for their content choice. Three pilot studies were conducted to develop, trial and refine items for the test instrument.

The Covalent Bonding and Structure Diagnostic Instrument consists of 15 items which refer specifically to the conceptual areas of bond polarity, molecular shape, polarity of molecules, lattices, intermolecular forces and the octet rule.

As most items were based on problem centred situations it was not possible to have

an item testing each specific propositional statement. As a result each item of the instrument tests a limited number of propositions. Content validity was ensured by basing the test's construction on the previously validated list of propositions. In addition, two experienced secondary school chemistry teachers and a tertiary chemistry educator reviewed the final items of the test instrument.

Subjects

The 15 item test instrument was administered to a total of 243 senior secondary chemistry students in South Australia. This group included 159 Year 11 students from 3 different co-educational high schools and from 8 different chemistry classes. Eighty-four Year 12 students took part in the study. These students were from 3 different co-educational high schools and 6 different chemistry classes. Both sample groups had a higher proportion of males compared to females in the ratio of approximately 7:3.

BOX 1

The Percentage of year 11 (n=159) and Year 12 (n=84) Chemistry Students selecting each Response Combination for Item 1 of the Covalent Bonding and Structure Diagnostic Instrument

Item 1

Which of the following best represents the position of the shared electron pair in the HF molecule?

(1) $\text{H} \quad \text{:}\ddot{\text{F}}\text{:}$ (2) $\text{H} \text{ : } \ddot{\text{F}}\text{:}$

Reason

- (A) Non-bonding electrons influence the position of the bonding or shared electron pair.
 (B) As hydrogen and fluorine form a covalent bond the electron pair must be centrally located.
 (C) Fluorine has a stronger attraction for the shared electron pair.
 (D) Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair.

Percentage of Student Responses

Year	Choice to first part	Reason				Total
		A	B	C	D	
11	1	1.3	2.5	43.4*	5.0	52.2
	2	6.3	33.3	8.2	0.0	47.8
12	1	0.0	3.7	61.4*	2.4	67.5
	2	2.4	22.9	7.2	0.0	32.5

* Correct response combination

Scoring of Items

A student's answer to an item was considered correct if the student selected both the correct content choice and the correct reason. Items of the test instrument were

evaluated for both correct responses and incorrect response combinations selected by the students. For example, the response combinations selected by Year 11 and Year 12 students in the sample for item 1 dealing with bond polarity are given in Box 1. Analysis of incorrect response combinations provided data on student misconceptions of the concepts and specified propositions tested by the item.

RESULTS AND DISCUSSION

The diagnostic test instrument was analysed using the usual testing procedures. The Cronbach alpha reliability was 0.73 when both the content and reason parts of the item were analysed. Difficulty indices ranged from 0.13 to 0.60 providing a wide range of difficulty in the items. Discrimination indices ranged from 0.32 to 0.65 and being greater than 0.30 were considered acceptable without the need for further revision of the test items (Lien, 1971).

When only the first part, the content answer, for each item was considered, students' correct responses on the 15 items of the diagnostic test ranged from 17% to 99% for Year 11 and from 40% to 100% for Year 12. When both parts of each item were considered, the correct responses were reduced to a range of 10% to 57% for Year 11 and 22% to 78% for Year 12.

The results from this study suggest that senior secondary chemistry students in this sample did not obtain a satisfactory understanding of most items being evaluated in the topic when the 75% correct criteria for a given sample of students was applied (Gilbert 1977). Furthermore, a comparison of the percentage of students who correctly answered the content part of the item compared with the number of students correctly answering the complete item suggests that students may have acquired accurate content responses without an adequate understanding of the concepts involved. Year 12 students' responses to the test instrument indicated, as might be anticipated, that they had a better understanding of the areas tested than did the Year 11 students. Although students' content understanding may often appear to be satisfactory using the 75% correct criteria, their understanding of the concept as measured through these items in many cases was less than satisfactory. The lack of understanding can be diagnosed in terms of misconceptions selected by students for each item.

For the purposes of this paper misconceptions have been listed where they were identified to exist in at least 20% of the student sample. The thirteen misconceptions identified in this study are shown in Table 1 and have been grouped for discussion under the headings of bond polarity, shape, polarity of molecules, octet rule, intermolecular forces and lattices.

TABLE 1

Percentage of senior secondary students with specific misconceptions identified from the Covalent Bonding and Structure Test Instrument

Misconception	Percentage	
	Year 11	Year 12
Bond Polarity		
1. Equal sharing of the electron pair occurs in all covalent bonds.	33	23
2. The polarity of a bond is dependent on the number of valence electrons in each atom involved in the bond.	22	-
3. Ionic charge determines the polarity of the bond.	26	-
Shape		
1. The shape of a molecule is due to equal repulsion between the bonds.	46	25
2. Bond polarity determines the shape of a molecule.	23	27
3. The V-shape in a molecule of the type SCl_2 is due to repulsion between the non-bonding electron pairs.	-	22
Intermolecular Forces		
1. Intermolecular forces are the forces within a molecule.	-	23
2. Strong intermolecular forces exist in a continuous covalent solid.	48	33
3. Covalent bonds are broken when a substance changes shape.	49	-
Polarity of molecules		
1. Non-polar molecules form when the atoms in the molecule have similar electronegativities.	40	34
2. Molecules of the type OF_2 are polar as the non-bonding electrons on the oxygen form a partial negative charge.	32	-
Octet Rule		
1. Nitrogen atoms can share 5 electron pairs in bonding.	-	20
Lattices		
1. High viscosity of some molecular solids is due to strong bonds in the continuous covalent lattice.	27	-

Bond Polarity

Thirty-three percent of students in Year 11 and 23% of students in Year 12 held misconceptions relating to bond polarity which indicated confusion regarding the unequal sharing and position of the electron pair in many covalent bonds. Students with this misconception appear to have correctly related electron sharing to covalent bonds, but

have not considered the influence of electronegativity and the resultant unequal sharing of the electron pair on bond polarity. Two other misconceptions identified among Year 11 students, by 22% and 26% respectively, involved the perceived influence of valence electrons and ionic charge on bond polarity. This latter misconception was evident when students were required to determine the correct polarity of the O-F bond. Students with this misconception considered that the oxygen was partially negative, as it can form an O^{2-} ion, whereas fluorine forms an F^- ion. Subsequently, students stated that the difference in magnitude of the negative charges on oxygen and fluorine resulted in the oxygen having a partial negative charge.

Shape

Three significant misconceptions concerning molecular shape were evident from an analysis of the items in the Covalent Bonding and Structure Test. Bond polarity, repulsion between bonds (only) and repulsion between non-bonding electron pairs (only) were three factors commonly identified by students as being responsible for molecular shape. When asked to predict the shape of NBr_3 , 23% of students in Year 11 and 27% in Year 12 selected a response indicating their belief that "bond polarity determines the shape of a molecule". In another question concerning the shape of $COCl_2$, the polarity of the $C=O$ double bond was identified as the factor determining the molecule's shape. A common misconception held by 46% of the Year 11 and 25% of the Year 12 students was that molecular shape was due to equal repulsion between bonds (only). When asked to predict the shape of the SCl_2 molecule students with this misconception identified SCl_2 as a linear molecule due to repulsion between the two S - Cl bonds.

An alternative view to the idea that molecular shape was due to repulsion between bonding electron pairs only was also identified. In this case 22% of Year 12 students considered that only the non-bonding electron pairs influenced the shape of a molecule.

Intermolecular Forces

Although the students in this sample were aware of the relationship between the strength of the intermolecular forces and the melting-boiling points of a substance a large percentage of students had some misconceptions relating to the meaning of intermolecular forces. In particular, intermolecular forces were incorrectly identified as the forces within a molecule by 23% of Year 12 students or the forces existing within a continuous covalent solid by 48% of Year 11 and 33% of Year 12 students. While this may be a case of mistaken terminology rather than a conceptual misunderstanding, it is worthy to note that such an incorrect choice occurred amongst students from 14 chemistry classes in 5 different schools.

The third misconception, occurring among 49% of the Year 11 students, illustrates students' confusion in describing the ability of viscous molecular substances to change

shape. Students with this view did not appear to recognise the role of intermolecular forces on the viscosity of molecular substances. As well, in attempting to explain this situation students indicated a misunderstanding of the strength of covalent bonds.

Polarity of Molecules

Two misconceptions were identified to exist when students attempted to establish the polarity of a molecule. The first misconception selected by 40% of Year 11 and 34% of Year 12 students identified non-polar molecules as those formed only between atoms of similar electronegativities. Generally students with this view did not consider the two factors, shape and bond polarity, when determining the polarity of a molecule. In this case students have identified bond polarity as a necessary factor but have not considered the influence of molecular shape. This misconception could be interpreted as incomplete understanding of the two factors required to ascertain a molecule's polarity.

The second misconception, selected by 32% of Year 11 students, identified the presence of non-bonding electrons as a factor in determining the resultant polarity of a molecule. This misconception could occur if these students compare the OF_2 molecule with the water molecule. The assignment of the partial negative charge to the oxygen could occur when these students compared the V-shape of the OF_2 molecule with the V-shaped H_2O molecule. Students may use a pattern matching technique (Lin, 1982) and apply their knowledge of the polarity of the O-H bonds in water to the O-F bonds in the OF_2 molecule. This could result in the oxygen in OF_2 being considered to have a partial negative charge.

Octet Rule

Students appeared to have some understanding of the octet rule principle. However, when applying this principle to a problem situation, an alternative view was that the number of covalent bonds formed by a non-metal equals the number of electrons in the valence shell. Twenty percent of the Year 12 sample considered that each nitrogen atom in the molecule N_2Cl_4 could share 5 electrons in bonding.

Lattices

The misconception, selected by 27% of Year 11 students, indicated confusion amongst the students on the nature and properties of covalent and molecular lattices. Continuous covalent lattices were attributed with molecular properties; in turn molecular lattices were often described as having characteristics of a continuous covalent lattices.

CONCLUSIONS AND IMPLICATIONS FOR TEACHING

The results of this study provide evidence to indicate that the students in this sample have not developed an appropriate conceptual understanding of the topic covalent bonding

and structure which is an integral part of the senior chemistry course in South Australia. Further, the misconceptions identified from administration of the test instrument to this sample of students have illustrated the nature of student understanding of specific components of the topic covalent bonding and structure. In this regard, a two tier diagnostic test instrument on Covalent Bonding and Structure does appear to provide a feasible approach for evaluating students' conceptual understanding and for identifying misconceptions.

The existence of these misconceptions is of direct relevance to teachers of chemistry at the senior secondary level. Teachers who are familiar with these misconceptions can develop instructional approaches which minimise the likelihood of these misconceptions occurring. Furthermore, based on this information, current instructional materials should be reviewed to ensure the concepts are taught at a level consistent with the students' cognitive abilities. However, additional work is still necessary to develop appropriate teaching/learning approaches which will assist teachers and students to overcome any misconceptions which the students may have acquired.

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Research In Science Education, 1986, 16, 49-54.

MODELS, METERS AND MEMORY

Colin Gauld

INTRODUCTION

Three notions have recently gained currency in the literature of conceptual change in science education. The first is that of the stability of pupils' frameworks in the face of teaching procedures designed to change them to more scientifically acceptable forms (Driver & Erikson 1983; Viennot, 1979; Watts, 1983). The second one relates to the internal coherence of pupil frameworks and their adequacy in making sense of phenomena experienced by the pupils (Viennot, 1979; Watts, 1983). The third is that of the regression of pupil conceptions to less scientifically acceptable ones following an affirmation by the pupil that the empirical evidence supports the more scientifically acceptable notion (Cosgrove & Osborne, 1985; Happs, 1985).

While the phenomena of stability and regression have been documented to some extent the rationality of the way pupils hold their frameworks (especially after conflict generated by carefully chosen empirical data) has not. A great deal of interest has been shown in what changes do occur in the models pupils adopt but there has been little emphasis on the reasons pupils appeal to in adopting them.

This paper outlines some of the ways pupils justify their ideas after experiencing a teaching sequence which has been specially designed to alter them. A fuller discussion of the investigation can be found in Gauld (1985).

THE TEACHING SEQUENCE

The study was carried out in a boys' high school in New Zealand about three months after a class of 14 year old pupils had studied the introductory topic of electric current in simple electric circuits using the three stage model developed by Cosgrove and Osborne (1983; 1985). In the first or focussing stage pupils constructed electric circuits designed to perform different functions, used various systems of representing the circuits on paper,

discussed with each other what they had done, and began to think about how they would explain what was happening in the circuits.

During the second or challenge stage pupils were asked to choose one of the four alternative models commonly used by pupils to represent the behaviour of the electric current in simple circuits. These models were:

- A. in which the current comes from one end of the battery and is all consumed in the globe;
- B. in which the current comes out of both ends of the battery and reacts in the globe;
- C. in which the current comes from one end of the battery, some is consumed in the globe and the rest continues back to the battery;
- D. in which the current comes from one end of the battery, squeezes through the globe filament and all returns to the battery.

Students debated with one another about the merits of their choices over those made by others. The role of the ammeter as a current measuring device was discussed and pupils were asked to predict, on the basis of their preferred model, the relationship between readings on ammeters placed before and after the globe. When the meters were connected (during the "critical" lesson) students discussed ways they could make sense of the meter readings, especially when these conflicted with expectations based on their original ideas. One pupil introduced the notion of a "carrier" model in which the "material" stored in the battery and "consumed" in the globe does not flow by itself through the wires but is transported by a second material substance which acts as a carrier. In this paper a carrier version of model A is designated by A(K).

In the third or application stage pupils designed circuits to solve practical problems outlined in the teacher's handbook.

DATA COLLECTION

About three months after the above three week sequence of lessons answers to the following questions were sought as part of interviews with 14 members of the class.

- (a) What model did the pupil adopt in order to make sense of what happens in a simple, series, electric circuit consisting of a battery, a switch, one (or two) globes and wires?
- (b) What was the pupil's idea before the lessons began?
- (c) What brought about any change of mind which occurred as a result of the sequence of lessons?

- (d) What ideas did the interviewee believe other pupils possessed?
- (e) Why were these other ideas believed to be incorrect?

Information was also available from data gathered by Cosgrove (Note 1) during the lesson sequence through interviews, recorded pupil discussions and a survey at the very end of the teaching sequence (Survey 1). The survey questions were presented to the pupils again (Survey 2) about two weeks before the interviews commenced.

THE OUTCOME FOR PUPIL P4

The arguments of pupil P4 have been chosen to present in some detail because data is available for this student from all phases of the teaching sequence and follow-up work and because the model this student adopted showed no change throughout the entire four month period. It therefore illustrates the stability against change often referred to in the literature about the effects on pupils of teaching in science. A similar degree of stability was exhibited only by pupil P1 who adhered to model B throughout the teaching and subsequent investigation.

Pupil P4 consistently adopted model C from before the time the lessons began to the time of the interview. Box 1 presents a summary of the arguments he used for adopting model C and rejecting other models of which he was aware.

As explained earlier A(K) is the carrier version of model A, while C(K) is the carrier version of model C in which some of the load (electricity) returns to the battery. In the model represented by -C the current circulates in the opposite direction to that in model C.

The data in Box 1 provide some evidence of changes which did occur in the cognitive context of the model adopted by pupil P4. The range of models of which the student was aware was probably broader than the range available to the student before the teaching began. Not only was the pupil aware of models A, B, C and D which were explicitly presented during the challenge phase but he was familiar with carrier models which were introduced by a pupil during the lessons and with the possibility that current could flow either way round a circuit. Three versions of model B were referred to by different students - the normal "clashing currents" form (P1), a combination of C and -C (P2) or, for pupil P5, a combination of A(K) and -A(K). Indeed, for all the pupils the final choice of model was probably made against a richer background of alternatives than would have initially been the case.

During the interview student P4 appealed to a more complex network of reasons than before to justify the choice of one model and to reject others. This was due partly to the greater number of alternatives which had to be considered and partly to the fact that

relevant evidence was available, as a result of the lesson sequence, which previously was not known to the student. The same state of affairs was found with all other students interviewed.

BOX 1

Summary of the Arguments of Pupil P4		
Stage of the investigation	Model	Reason
Challenge Phase	C	(because) I'm pretty sure electricity travels round in a circuit.
	C	it must go round in a circuit. Some must come back otherwise it'd go flat too fast.
	Not A	because if that dotted wire has no electrical current then it will be like not having a wire there. And we've worked out that you have to have two wires connected for it to go.
Survey 1	C	
Survey 2	C	
Interview	Not B	because during the studies we've done in science I think that one's been proved to be wrong.
	C	(confirmed because) the meter here was more than this one but I'm not sure what they actually read ... I think this one here was double that one.
	Not A(K)	(because I think) some would have to go back.
	C(K)	well that's sort of my view - (the meters are measuring the electricity not the trucks).
	Not D	briefly (came across that idea) but that was proven wrong by the meters.
	Not -C	(because) we found out the direction of it too. The direction of the electricity was this way - I can't remember how we did it.

For a number of students the coherence of their arguments depended on the fact that their memories of meter readings (or of the relative brightnesses of two lamps in series) were not correct. The reason why pupil P4 could appeal to the meter readings to support model C (see Box 1) was that he had an apparently clear memory that the second meter gave a larger reading than the first as would be expected if the lamp had consumed a certain amount of electricity. On the other hand P14 rejected model C because his memory was that the meter readings were equal. In many cases consistency existed because "memories" were apparently reconstructed from implications of the adopted model. This conclusion is reinforced by the fact that most pupils believed that the large majority of other pupils had adopted the same model that they had. That this was not the case is shown by the variety of models adopted during the interviews (see Table 1).

TABLE 1
Models Adopted by Pupils During the Interviews

MODEL NUMBER OF STUDENTS	B	C	C(K)	A(K)	D
	2	1	3	7	1

In some cases inferences could be drawn only if a model was elaborated further and the relation between the empirical evidence and the model depended on the way in which this elaboration occurred. For example, P10 used a memory of equal meter readings to support model A(K) because he believed that meters measured the flow of carriers. On the other hand, P11 could justify the same model by appealing to a memory of unequal meter readings since he believed that the meters measured the amount of load carried.

CONCLUSION

All pupils ended up relating their models to a broader range of evidence and reasons. Even those students who did not change their basic models were able to defend them against a wider range of alternatives by referring to a richer domain of reasons. While the crucial importance of the empirical evidence was implicitly acknowledged by all, in a number of cases the coherence of the point of view was achieved because "memories" of empirical evidence were apparently reconstructed to be consistent with the model adopted.

Because the pupils seem to have acquired, after two or three months, a sound network of arguments which relate models to evidence, it is likely that some beliefs which are based on erroneous memories of the evidence could be dealt with by later lessons in which the relevant facts are presented again. This conclusion is consistent with Arzi's notion that conceptual development through teaching should be seen as a long-term, continuous rather than as a short-term, discontinuous process (Arzi, 1985).

In most cases, but not all, the model which a pupil adopted during the interview was different to any that were available before or immediately after the critical lesson. For ten of the fourteen pupils this involved the adoption of a carrier model rather than the non-carrier model previously used and for seven it was a carrier version of model A. No pupil had approved of model A before the critical lesson.

In the light of these conclusions the notion of regression to earlier models may need some clarification since it is likely that the view a pupil might return to is located in a richer mental context than was the original view. In this sense a pupil will rarely retain or

return to a former position. Evidence is also provided by Cosgrove (Note 1) that asking pupils to choose a model immediately after the critical lesson does not indicate a position to which they are strongly committed and so may not be a position from which they then "regress". Beliefs take time to become established so that research into the effects of teaching should focus on long-term changes which occur rather than on the more tentative "trialling of alternatives" which may take place during and immediately after instruction.

NOTES

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Research In Science Education, 1986, 16, 55-62.

PRIOR KNOWLEDGE AND PRIMARY PUPILS'
INTERACTION WITH A MUSEUM DISPLAY

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There are many opportunities outside the school program, such as visits to zoos and museums, for children to learn about the natural and technological world. The question of what factors determine the effectiveness of such opportunities has received some attention from researchers. Lucas (1983) has produced a review covering research into science learning in informal settings. One area of research, which such reviews show to be somewhat neglected, concerns the extent to which the prior knowledge of the visitor affects the learning which occurs when people visit museums, zoos and other such venues. The aim of the research reported here was to contribute to the correction of that deficiency.

THE SETTING OF THE RESEARCH

In order to study the impact of prior knowledge on interaction with a museum display it was decided to focus on a topic about which most children and adults were likely to have some relevant ideas. Accordingly, that part of a display concerned with relating skeletal structure in animals to their function, mounted by the Museum of Victoria, which dealt with skulls, teeth and diet was chosen as the focus of attention. The display consisted of 10 skulls arranged in 2 groups. One group comprised the skulls of carnivores: a capybara, an elephant, a wombat, and a yak. Each skull was labelled with the name of the animal and the whole group was accompanied by a sign which read 'Plant Eaters'.

The second group consisted of the skulls of 6 carnivores: a dolphin, a croaker, a crocodile, a seal, a polar bear and a shark. Again each skull was labelled with the name of the animal and the whole group was accompanied by a sign which read 'Meat Eaters'.

TABLE 1

Classification of the responses of pupils (n=154) to the request to suggest the diet of the animal when

(a) provided with the animal's name only

(b) provided with the name and a photograph of the skull of the animal

Animal	Category of response	Number of responses of pupils (n = 154) in a category when given	
		(a) name only	(b) name and photograph of skull
Bottle-nosed Dolphin	Herbivore	1*	1*
	Carnivore	124	129
	Omnivore	5	6
	No response	23	17
Elephant	Herbivore	126	114
	Carnivore	6	5
	Omnivore	6	10
	No response	16	25
Leopard Seal	Herbivore	1	3
	Carnivore	112	112
	Omnivore	3	1
	No response	38	40
Polar Bear	Herbivore	1	2
	Carnivore	140	137
	Omnivore	0	2
	No response	13	13
Wombat	Herbivore	90*	93
	Carnivore	23	23
	Omnivore	10	6
	No response	30	30
Yak	Herbivore	52	57
	Carnivore	33	39
	Omnivore	8	4
	No response	61	54

* 1 response indecipherable

DATA GATHERING CONCERNING PUPILS' KNOWLEDGE OF DIETS

Even young children carry with them a vast memory store, and it is important to ask what parts of that store are likely to influence their interaction with any particular display. It was considered that familiarity with the diets of animals, and knowledge of relationships between diet and dentition, could be particularly relevant to the display

being considered. Accordingly it was decided to gather information using a paper and pencil exercise, about primary school pupils' background in this area. On the first page of the questionnaire devised for the study were listed the names of six of the animals (3 herbivores and 3 carnivores) whose skulls were included in the museum display. The children were told that, if they knew or could guess what the animal ate, they should record this information.

On the following pages the same information was sought but, in addition to the names of the animals, photographs of their skulls were provided. These photographs were included in order to see the extent to which providing some information about the dentition of the animals influenced the pupils' notions about the animals' diets.

The subjects for this part of the study consisted of all of the pupils in Grades 3 to 6 at a Melbourne primary school. The class teachers agreed to take the children through the questionnaire, reading the instructions so that the response was not influenced by reading ability. There were 154 pupils involved, with roughly equal numbers at each of the 4 grade levels.

The Data

Part of the analysis of the data is shown in Table 1. (The analysis across grade levels showed no differences between the knowledge of the children at the different grade levels.)

Whilst the vast majority of the children made suggestions about the diets of the dolphin, elephant, seal and polar bear that correctly placed them as herbivores or carnivores, there was less widespread knowledge of the diets of the wombat and yak.

The analysis further shows that the provision of reproductions of photographs of the skulls had insignificant impact on the children's ideas about the diets of the animals. This could be due to the lack of definition in the reproductions, or it could be that the children who had no knowledge of the animals' diets also lacked knowledge of the relationship between diet and dentition.

DATA GATHERING AT THE MUSEUM

Data were gathered at the museum by interviewing 43 of the primary school children in grades 3,4,5 and 6 who came in class groups to that section of the museum which housed the display in question. The children were advised that after they inspected the display they would be questioned about it. The interview consisted of 4 parts. Initially the children were asked whether they had noticed that the skulls were grouped and, if so, what the basis of the grouping was.

After this they were asked to identify the diets of the six animals in the display

which had been the focus of the earlier classroom study. The subjects were asked to state, for each animal, the source of the information they supplied.

In the third section of the interview the children were shown the skull of a carnivore and that of a herbivore and, for each, asked to infer what the diet of the animal might have been. Again the children's reasoning was sought.

In the final section of the interview the child was given the opportunity to ask questions about the display. These were recorded and answered to the best of the interviewer's ability.

All of the responses were recorded in longhand by the interviewer on a proforma developed as a result of trials.

Independent Variable

It was decided to introduce, as an independent variable, the use of a sign 'Look At The Teeth'. This sign was placed in a prominent position in the centre of the display for the time that half of the children from a particular school were using the display.

TABLE 2

Relationship between awareness of the grouping of the skulls and the diet of the animals displayed.

Animal	Number of pupils aware of the groupings and correct in their ideas about the diet of the animal n = 19	Number of pupils unaware of the groupings and correct in their ideas about the diet of the animal n = 24
Bottle-nosed Dolphin	14	20
Elephant	16	15
Leopard Seal	14	18
Polar Bear	17	20
Wombat	13	7*
Yak	12	5*

Chi-square values reveal that the difference is significant at the .01 level.

Analysis of the Data

Only 44% of the pupils were aware of the grouping of skulls into herbivores and carnivores. Examination of the data presented in Table 2 reveals that awareness of the grouping was associated with correct knowledge of the diets of the wombat and yak. The argument for a causal relationship is supported by the fact that a significant number of

the pupils referred to the grouping, when justifying the diet they had suggested. (For the wombat and yak 25% and 33% respectively of the pupils referred to the grouping of the skulls.)

TABLE 3

Numbers of pupils able to correctly suggest the diet of the animal when shown the "unknown skull".

	Number of correct suggestions	Number of incorrect suggestions	Number of "don't know" responses	Total
Subjects exposed to the label directing attention to the teeth. (n = 23)	30	9	7	46
Subjects not exposed to the label directing attention to the teeth. (n = 20)	26	10	4	40
TOTAL	56	19	11	86

TABLE 4

Questions asked of the interviewer when the subjects were given the opportunity.

Question	Number of times posed
1. What is a croaker?	3
2. What is a capybara?	2
3. How do you find out what sort of animals they are?	1
4. How does a dolphin's jaw work?	1
5. How come all the croaker bones were like that?	1
6. Is that a normal elephant?	1
7. How come a shark has rows of teeth?	1
8. What does the yak eat?	1
9. How did they put the skulls together?	1
10. Are they all real?	1
11. How big do tiger sharks get?	1
12. Why is it called a leopard seal?	1

It was anticipated that the directive to look at the teeth could result in a greater proportion of the pupils being able to correctly suggest the diet of the animals when shown the unknown skulls during the interview. Inspection of Table 3 shows that this was not the case.

Relatively few questions were asked when the children were given the opportunity. Those asked are listed in Table 4.

Inspection of the Table shows that none of the questions related to the particular focus of the study, the relationship between teeth and diet. There is one question (7) relating to teeth and another (8) related to diet.

DISCUSSION

The findings of this study have implications both for those responsible for displays in museums, and like places, and for teachers. It is acknowledged that some (Alt, 1977; Clark, 1978) have argued that museum displays are not primarily concerned with education and that it could also be argued that not all displays need to be understandable for primary school pupils. There will be no attempt to debate these issues here.

The comments which follow are based on the belief that museum displays should be designed in such a way as to maximize the number of people who benefit from them. Further it is assumed that what the study has revealed about young museum visitors will be a useful guide to the potential of the display as a learning resource for older visitors.

The Choice of Skulls and Visitors' Knowledge of Diets

Quite clearly the children, whilst knowledgeable about the diets of some of the animals whose skulls were displayed, were not so knowledgeable about others. If all of them read the labels which established the grouping of the skulls this would probably not matter greatly. In fact, in this study for some children reading the labels expanded their knowledge of the diets of animals. However, less than half of the children read the labels and so were aware of the grouping. In this context knowledge of the diets of the animals whose skulls are displayed would be essential if the children are to associate diet and teeth, as was the intention of those who designed the display.

This suggests two alternative courses of action. One is to ensure that the animals displayed are those whose dietary habits would be known to the vast majority of museum visitors. This study has shown how easily such information can be obtained for school children. The alternative would be to provide information about the animals' diets. This could be done by photographs or by including as part of the display examples of the food eaten.

The Choice of Skulls in Relation to the Objective

When the pupils were asked, after viewing the display, to identify the likely diets of animals, when given only the skulls, about two-thirds of the responses were appropriate. What of the remaining one-third?

The data discussed earlier suggest that some of the children would not have read the directive to look at the teeth. On the other hand, some are likely to have done so, but there is no evidence to suggest a positive outcome from reading the directive. Admittedly the procedures for detecting such an outcome were limited. However it is worth asking whether the display itself was ideal for the purpose.

The dentition of the animals represented in the herbivore group was quite diverse. Apart from the absence of canine teeth there was little in common between the animals with respect to their dentition. For the uninformed visitor it might be easier to detect the differences in dentition than the similarities. If a display aims to increase the number of visitors able to distinguish the skulls of herbivores from those of carnivores, by reference to the teeth, the choice of skulls is crucial. The dichotomy is itself a significant simplification and so the skulls for display would need to be chosen from a limited range of those which most clearly illustrate the simplified generalization.

Implications for Preparing Children for a Museum Visit

This study showed that most middle and upper primary school pupils would bring to this display a good deal of knowledge relevant to the focus intended by those who designed the display.

However the indications are that this knowledge did not direct the attention of many of the students while they looked at the display nor was it changed by their interaction with the display.

The questions that the children asked after viewing the display, and even after being involved in an interview which focussed their attention on diet and dentition, show that their interaction with the display rarely, if ever, followed the path envisaged by those who designed it.

One reason for this would appear to be the fact that the majority did not use the labels which indicated the grouping of the skulls.

Gennero (1981) showed the benefits resulting from pre-visit orientation. Students who received advanced instruction on what they would be seeing at the museum learned more than those who didn't. It isn't always possible to brief students on everything they will see at a museum but what teachers can do is to help pupils develop strategies which would enable them to gain maximum benefit from such displays. Part of this process would involve discussion of the functions performed by labels in museum displays. If children were encouraged to ask themselves "What is this display designed to help me

learn?", and to seek an answer in the labels provided, before becoming engrossed in the objects displayed they may gain greater benefits from such displays.

CONCLUSION

The study was developed within the constructivist tradition which stresses the importance of prior knowledge in determining learners' interaction with the world around them. Accordingly, information was gathered about primary school children's ideas about diet and dentition in animals, since it was assumed that this would determine the learning that would take place when they observed a display of skulls based on a structure-function generalization about teeth. In retrospect it seems a pity that the subjects weren't asked what they thought were the purposes of labels in the museum, as an appropriate use of labels seems to be crucial in determining whether the objective of the display is realized.

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HEALTH AND SICKNESS CAUSATION AND THE INFLUENCE OF THAI CULTURE AMONG THAI SCHOOLCHILDREN

Pranee Rice and Richard Gunstone

INTRODUCTION

Among the major developments in science education has been the study of the knowledge about natural phenomena that children bring to classrooms. Children develop their knowledge while attempting to make sense of natural events they encounter. This knowledge is sometimes developed from children's interaction with everyday experience (Driver & Easley 1978; Osborne & Bell 1983). It is also derived from the culture in which they are brought up - that is from values, customs, language, religions, beliefs and their social and physical environment (Hewson 1983; Maddock 1983). Children, as a result, often bring to school a form of knowledge which is considerably different from school knowledge.

In this paper we consider out-of-school knowledge to have two forms: commonsense knowledge and cultural knowledge. Children's commonsense knowledge is frequently not well known to teachers or to researchers, but to children it provides very sensible and practical explanations (Osborne & Schollum 1983). It refers to everyday interpretations acquired by children without formal instruction (Shweder 1977). Cultural knowledge refers to the views of knowledge shared by people in a group and learnt by their children. It is based on the experience of older generations and passed on to younger generations (Mandelbaum 1979; Norman 1981).

Differences in cultural knowledge and school knowledge are remarkable (Maddock 1983). This is particularly so among non-western children. It has been noted elsewhere (Maddock 1981) that children from such countries as India, Papua New Guinea and Thailand hold interpretations of events which are markedly different from school views. Similarly, Hewson (1982) points out that the knowledge of children from non-western cultures and backgrounds are more divergent from school knowledge than children who are brought up in a Western environment.

The differences between commonsense knowledge, cultural knowledge and school

knowledge are important in the classroom. Freyberg, Osborne & Tasker (1980) suggest that teaching would be improved if teachers make attempts to appreciate the beliefs and interpretations that children bring to the classroom.

This present study is part of ongoing research. It considers the interpretations of the causes of health and sickness among Thai schoolchildren. It seeks to find out how Thai schoolchildren perceive the causes of health and sickness, what reasoning patterns they employ, and to what extent the culture in which they have grown up influences the views of knowledge they bring into the classroom. The purpose is to provide a basic understanding for teachers in Thailand and elsewhere to maximize effective learning situations in the classroom.

PROCEDURES

Subjects

The subjects were Thai schoolchildren who are inhabitants of Phuket province, a semi-rural province in the south. Forty-eight schoolchildren selected from four schools in the region were individually interviewed. These included twenty-four children from the Pratom 6 Class (year 6 of primary school) and twenty-four children from the Matayom 2 Class (year 2 of secondary school). These two grade levels were chosen because the concepts of health and sickness and their causes are taught in detail in Matayom 1 (year 1 of secondary school) after being briefly considered in Pratom 4 and 5 (years 4 and 5 of primary school). A stratified random sample was used. This gave equal numbers in terms of religious background (Thai-Buddhism and Thai-Muslim) and in terms of gender.

Method

The study employed the "Interview-about-Instances" technique developed by Osborne and Gilbert (1979) to obtain data. Seven photographs illustrating people of different appearance were provided to the subjects. They were asked to look at the photographs, one by one. They then were asked to discuss how the people in the photograph appeared to them and to explain why. Lastly, they were asked what causes might contribute to that person's health and sickness.

The interviews took between 30 to 45 minutes and were recorded on a tape-recorder. They were individually transcribed to obtain a written record for detailed analysis. The interviews were conducted in Thai language. They were later translated into English to present exemplars.

Data Analysis

The transcripts were analysed using the Conceptual Profile Inventory (CPI) technique developed by Erickson (1979). The transcripts were carefully examined for the

explanations given by each subject. The given explanations, then, were extracted, categorized into groups and short descriptions representing the explanations expressed by the subjects as a whole were produced. The number of subjects who gave each form of explanation was determined. Word-by-word examples from the transcripts are used to show the subjects' explanations.

RESULTS

There are three main findings from the interview data. First, Thai schoolchildren use their cultural knowledge to explain the causes of health and sickness. Religious and animistic beliefs including "Kam" or "Baab" and supernatural power are found among the children. "Kam" is believed to be the root cause of any suffering including sickness. It is the result of demerits accumulated by misdeed in the past. Therefore, "do-good-make-good" results in good health, prosperity, birth in heaven and good fortune. On the other hand, "do-bad-get-bad" causes misfortune, suffering, sickness in the present life and reincarnation in hell or in an animal form. (Kunstadter 1978; Meucke 1979). Supernatural power such as black magic and the powerful spirit has a punishment ability causing sickness or perhaps death. Buddha amulets, on the contrary, protect human beings from any harm such as ghosts, poison animals and human aggression.

Thai customs are evident among the children's explanations. Being looked after by descendants is an example. Traditionally, parents are looked after by their descendants when they are old. Since parents are the ones who give birth, children ought to be grateful and repay the kindness. This also leads to "Boon" (merit) and "Baab" or "Kam" (demerit) mentioned before. Being looked after well causes parents to have good health and their descendants to have "Boon". Being neglected, on the other hand, results in sickness for parents and "Baab" for their descendants. Thai children, girls in particular, are taught to help their parents do housework such as sweeping and washing floors, cooking and looking after their younger brothers and sisters from a young age. It is believed to result in good health.

Severe disabling disorders such as seizure, mental retardation and congenital deformities are believed to be sicknesses caused by parents and "Kam-ma-pan" (Muecke 1979). Sickness caused by parents occurs during pregnancy. "Rook Kam-ma-pan" is an illness which is repeated in the family. It is inherited from parents, particularly from the mother since she conceives the baby.

Sickness is also caused by food eaten among the Thai, for instance, eating food which is "salaeng" (wrong or bad) to the body, as it is said "Ahaan Salaeng" (Muecke 1979). Certain kinds of foods are typically more "salaeng" or bad than others. Hot shrimp paste

sauce, hot and spicy curry, pickled foods, half-done food are cases in point. Additionally eating fruits or vegetable which have small seeds is believe to result in appendicitis.

The socioeconomic status of the country is considered to be one cause of sickness among the Thai. Thailand is a developing country: the majority of Thai people are peasants, low-paid waged workers or unemployed (Girling, 1981). Most are poor and a large number are uneducated. Consequently they become low-paid labourers or beggars, which means there are a number of beggars on streets, begging for food. Some days they receive enough to buy food but not so on others. Also, Thai families tend to be large, and a family cannot afford enough food.

Second, Thai schoolchildren employ their commonsense knowledge to interpret the causes of health and sickness. Family, for instance, may cause good health or sickness. This includes the way parents look after the children and the way family members treat each other. Health and sickness may be caused by environment, for example, the country side, polluted area, or slum, people around and animals prevalent in the area.

Living conditions (e.g. filthy and clean) may contribute to good health or sickness. If one doesn't wash one's hair and keeps it too long, one will have lice which suck blood. Nature causes good health and sickness. Being exposed to such natural events as dew, rain, sun and wind results in sickness. The nature of human beings also contributes. Old age makes one sick. Young age, however, makes one healthy: it occurs in the eating period.

Food which contains dye-color, particularly bright colors like red and green, harms health. Food seasoned with monosodiumglutamate also causes sickness. Alternative exercises such as doing housework, walking to have a talk with friends or children running around results in good health.

Sickness may be caused by negligence and ignorance, such as picking food from streets or not wearing shoes. Good health results from looking after oneself well. Emotion and mind may cause health and sickness. If emotion is disturbed (being anxious, unhappy), sickness occurs. On the contrary, having high spirit and will power results in good health.

Third, school knowledge taught from the classroom is used by the children. Interestingly, though the concepts used are school knowledge, the nature of explanations is very often still an everyday interpretation. For instance, a person is sick because "she doesn't do exercises. It makes her feel weak and no power. When she fights she will be defeated" (Benjamas Grade 6).

Food is seen to be a cause of health and sickness. Eating good food such as rice and meat results in good health. Eating spoiled foods, however, causes sickness. Germ and disease cause sickness. These include a disease germ, a worm and such diseases as

malnutrition, polio and growth tissue. Accicent, poison and explosion causing physical deformation may contribute to sickness. Such accidents as falling down from steps and poisonous chemicals sprayed around houses and factories cause sickness.

Health and sickness are also caused by human's habits. These include eating habits such as eating at a time one should, doing exercises, drinking, smoking and consuming drugs and knowing the limits of the body. Biomedicine such as body resistance, injection, vaccine contribute to health and sickness. If one has high body resistance and a vaccine to prevent diseases, one is healthy and vice versa.

The descriptions of the knowledge categories identified from the data analysis as well as the number of children who expressed them are given in the Conceptual Profile Inventory which follows. Exemplars are presented and cross-referenced with the children's first name and grade level.

Conceptual Profile Inventory for the causes of health and sickness:

CPI Category	Exemplars
<u>A. Thai Cultural Knowledge (280)</u>	
<u>A1 Religious and animistic beliefs (11)</u> Sickness is caused by "Kam" and supernatural power.	"I think it is because of Kam. I mean she might do something bad in her past life, probably hit someone's back." WILAIWAN G.8
<u>A2 Customs (69)</u> Thai customs such as descendants look after their parents, children are taught and trained may contribute to health and sickness.	"He might get spelled by black magic. He might steal people's fruits and cause troubles. These people were angry so they casted a spell on him." SUPAPORN G.8 "He has a son married to a woman who dislikes him. His son loves his wife too much to listen to her and throws him out." SUKON G.8
<u>A3 Traditional Healers beliefs (67)</u> Congenital deformities are caused by parents and "Rook Kam-ma-pan."	TUANJAI G.6 "His mother wants to get rid of him. So she takes pills. The baby doesn't die but comes out like this. His mother feels ashamed because she is still a student." JITTIMA G.6

CPI Category	Exemplars
A4 <u>Ahaan Salaeng (57)</u> Eating bad food causes sickness.	"It is a "Rook Kam-ma-pan." His grandparents might have this disease. Sometimes the parents have bad essence causing the baby born abnormally." ANUSORN G.8 "My brother was sick so my mother did not allow him to eat chicken or the fish which has scales. She said if you eat them, they make you itchy and then sicker because they are salaeng."
A5 <u>Socioeconomics (76)</u> Social and economic status has an effect on health and sickness.	WANDER G.8 "He suffers appendicitis because he eats ripe guavas." AKOM G.6 "Thai people are poor. When they have children, it is very difficult." SUKON G.8 "He has no education to get a job so he has to wander on streets and beg for food. Sometimes no one give him so it makes him suffer from not having food."
B. <u>Commonsense Interpretations (470)</u> B1 <u>Family (73)</u> Health and sickness are affected by members of the family.	SUCHAT G.8 "His mother hits him too much. When he is younger whenever he cries, she hits." KOMKRIT G.6 "The outsiders induce the families to be disunited and usurp her properties."
B2 <u>Environment (85)</u> Health and sickness are caused by environment in which one lives.	ADISAK G.6 "She dresses up like this indicate that she lives in the country side. It is unlike in the city because there is no traffic jam and the air is fresh." BENJAMAS G.8 "She lives in a slum. It is bad because it is crowded and dirty..."
B3 <u>Living Conditions (90)</u> How one lives has an influence on one's health.	AREE G.8 "When having a shower he doesn't rub excretion or doesn't do properly. It makes his body dirty results in sickness..." SURASIT G.8

CPI Category	Exemplars
B4 <u>Nature (37)</u> Health and sickness may result from natural events and human nature.	"Her hair is dirty so she has lice. ... it sucks the blood from our head. It makes us getting thinner because it sucks the blood from our body. When it sucks our blood from our head, our brain is also on our head, it makes us unable to understand and unintelligent." ANAWAT G.8 "Probably the wind gets into his belly ... He doesn't have things to eat so the wind gets inside instead." ANUSARA G.6 "She is in the period of old age. It is easy to get body-ache and sick."
B5 <u>Food/Alternative Exercises (43)</u> Food contained dye-color, swarmed by flies and seasoned by monosodiumglutamate as well as knickknack food causes sickness.	SUCHAT G.8 "He eats food contained color... Color like the bright red is unhygienic but light color is alright. Dark green is not good but light green as a screw pine leave is good."
B6 <u>Negligence/Ignorance/Care (108)</u> Sickness happens when one is careless and ignorant whereas good health results from looking after oneself well.	TUANJAI G.6 "She does houseworks at home... such as growing lemon glass..." SANIT G.8 "It is because of carelessness and ignorance. He doesn't want to wear shoes because they costs money. He walks bare feet and then steps on sharp things."
B8 <u>Emotion/Mind (34)</u> If one's emotion is disturbed and one has no will power, sickness results.	WIJIT G.6 "She doesn't wear top. She might get pneumonia in winter and cracked skin in summer." PRAKIT G.6 "She is unhappy, anxious and think about problems. It makes her mental health deteriorated." KRIENGSAK G.8 "He no longer sees the importance of his life because he is neglected. He loses his heart."
C. <u>School Knowledge (231)</u>	AKRADET G.8
C1 <u>Food (80)</u> Eating good and useful food contributes to good health.	"She eats useful and good quality food ... such as fruits, vegies and fish..." KECHA G.6

CPI Category	Exemplars
C2 <u>Germs/Disease (48)</u> Sickness is caused by germs, worms and diseases.	"He drinks smelly water. The smell is from a dirty container. The water she drinks may not be boiled clean enough and contained an animal, a worm." ORACHORN G.6 "There are disease germs get into her body through her skin and mouth." ORATAI G.8
C3 <u>Accident/Poison/Explosion (26)</u> Sickness is resulted from having accident, being exposed to poison and explosion	"She falls down from steps or a heavy thing falls on her back causing her to have a broken back." SREERIN G.6 "He might be exposed to poison chemical. People spray poison chemical around their house to kill insects, grass or mosquitoes." WANDEE G.8
C4 <u>Habits (67)</u> Human's habits contribute to health and sickness.	"She eats food at the time she should otherwise she will feel uncomfortable and have a stomacheache." NIRAL G.6 "He is a drug addict because he wants to try it and excepts food from strangers and wants to get away from troubles in his life...." PRACHARAT G.8
C6 <u>Biomedicine (10)</u> Body resistance, vaccine and injections have effects on health and sickness.	"She has body resistance that makes her strong and do not get sick easily." BENJAMAS G.6

CONCLUSION

The findings show that Thai schoolchildren interpret the causes of health and sickness using their cultural knowledge and commonsense knowledge as well as school knowledge learned in the classroom. The cultural and commonsense knowledge are remarkably different from what they are taught. More importantly, when the children employ school knowledge, the explanations are still very much commonsense interpretations.

What do these findings imply then? They suggest that despite lengthy training in the classroom, the influence of the culture in which the children are growing up and their everyday experiences play an important role in their learning process. The basis of their

understanding of the causes of health and sickness still seems to be in cultural and commonsense knowledge.

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Research In Science Education, 1986, 16, 73-81.

SCIENCE TEACHERS' CONCEPTS IN NIGERIA AND AUSTRALIA

Catherine Ameh and Richard Gunstone

INTRODUCTION

This paper reports on the ideas of science held by Secondary School Trainee science teachers across two countries: Nigeria and Australia.

Students' ideas about natural phenomenon have been widely investigated (Stead and Osborne, 1981; Osborne and Gilbert, 1979; Champagne, Gunstone and Klopfer, 1983; Nussbaum and Novak, 1979).

Although researchers have recognised the role of teachers by urging them to probe students' concepts before they can effectively teach them (Osborne, 1980, 1982; Gunstone and White, 1981) there is no known research report on the ideas teachers themselves have in science.

Because of this, seven concepts were selected from the learning in Science Project (New Zealand), and administered to fifteen (15) graduate trainee science teachers enrolled at the University of Jos in Nigeria for a Post Graduate Diploma in Education and forty-two (42) graduate trainee teachers at Monash University enrolled for a Diploma in Education. A paper and pencil test was used. Some preliminary results for the Monash group have already been reported (Ameh and Gunstone, 1985). Results of responses are presented for each concept and comparison made.

Data Collection (Sample)

Forth-two Secondary science trainee teachers at Monash took the test in the 4th week of their course. Fifteen secondary science trainee teachers at Jos (considered to be a group equivalent to the Monash group) took the same pencil and paper test in the 4th week of their enrolment at the University of Jos, Nigeria. Because the system of education in Nigeria is structured on the British system, and because English is the official language of Nigeria, the comparison is considered appropriate. Each group took about the same time to write the test, i.e. between 45-60 minutes. The test was administered during a regular lecture time in their course. All took the test very seriously. All subjects had a degree in science.

RESULTS

CONCEPT OF ANIMALS

Sixteen instances and non-instances of animals were presented. There are two parts to each question. A) requires the respondents to tick the appropriate answer (Yes or No); B) requires the respondents to give reasons for their choice.

Table 1 shows the examples presented and the extent of incorrect responses.

TABLE 1

Examples given for the concept "Animal" and Numbers of Incorrect Responses.

Examples given	PGDE Nigerian Sample (N = 15)	Dip. Ed. Australian Sample (N = 42)
Frog	1 (7%)	-
Snail	2 (13%)	4 (10%)
Rabbit	0	0
Bat	2 (13%)	-
Cow	0	0
Worm	2 (13%)	2 (5%)
Fish	2 (13%)	1 (2%)
Boy and Girl	1 (7%)	2 (5%)
Fly	3 (20%)	3 (7%)
Grasshopper	1 (13%)	4 (10%)
Bird	1 (7%)	-
Lizard	2 (13%)	1 (2%)
<u>Non-Examples</u>		
Car	-	1 (2%)
Lettuce	0	0
Fire	0	0
Grass	0	0

Reasons for saying an instance is not animal

Snail

- PGDE "Produces its young through laying of eggs - animals don't lay eggs"
- Dip.Ed. "Not as complex as animals, has simple basic structure for survival"
- Dip.Ed. "Class gastropoda"
- Dip.Ed. "Phylum Mollusca, it is soft inside has an external protective covering"
- Dip.Ed. "Cold blooded, multicellular"

Bat

- PGDE "can fly, animals don't fly"

Worm

PGDE "Produces its young through laying of eggs"

Dip.Ed. "No skeleton, it's an anthropod"

PGDE "It lacks the general properties of animals"

Dip.Ed. "Does not have a complex system as animals has simple structure for survival"

Fish

PGDE "Produces its young through laying of eggs" "Lacks general properties of animals"

Dip.Ed. "No, because it does not live on land, no limbs, etc."

Boy and Girl

PGDE &

Dip.Ed. "They are humans"

Fly and Grasshopper

PGDE &

Dip.Ed. "They are insects"

Lizard

PGDE "Lizard produces its young through laying of eggs" "Lacks general properties of animals"

Dip.Ed. "Lizard is not a complex animal"

Criteria used for accepting that an instance is an animalPGDE

Often mentioned movement. One respondent referred to holozoic feeding. One used developed sense organs and one mentioned feeding on already manufactured food. Most of the other respondents gave characteristics of living things which are common to both plants and animals. Three others mentioned quite unexpected characteristics:

- * Presence of limbs * no chlorophyll * Possession of soul

Dip.Ed.

This group used words like heterotrophic feeding (30.9% of respondents), nervous system (14%), movement (57%), cell structure (26%), digestive system (7%). Most of the others listed characteristics that are common to both plants and animals.

One noticeable attribute among Dip.Ed. and not PGDE was the mention of ATP (2%) or DNA/RNA (21%). While some PGDE used holozoic, Dip.Ed. used heterotrophic.

FORCE

Force in a dynamic situation was presented via a person throwing a tennis ball upwards. Questions were asked about the total force on the ball when it was going up, when it was at its maximum height, and when it was coming down.

Responses are shown in Table 2 in terms of "up", "zero", "down" for the force. The order of responses is for the ball on the way up, then at maximum height, then the ball on the way down.

TABLE 2
Responses to "Forces on a Ball"

	PGDE (N=15)	Dip.Ed. (N=42)
down, down, down	1 (7%)	13 (31%)
down, up, down	1 (7%)	-
up, zero, down	10 (67%)	23 (55%)
up, down, down	2 (13%)	-
down, zero, down	1 (7%)	4 (10%)
others	-	2 (5%)

Respondents were also shown a diagram of a person on a bike, moving but no pedalling or braking, and asked if there was a force on the bike.

For the PGDE sample, 12(80%) respondents said there was a force on the bike. The reasons given included -

- . "Yes, gravity is always acting on an object on the earth's surface, since it is in contact with the earth's surface, there is frictional force."
- . "A strong wind could be blowing against it, friction between the tyres and the ground, the ground could be quite rough and a little hilly."
- . "The force is that of the rider and gravitational force."
- . "Force of retardation."
- . "The force, acquired as a result of the initial velocity and the mass of the bike."
- . "It is only force that keeps something moving or stopping."
- . "Because the man is applying the force."
- . "The force causes the movement and the gradual slowing down."
- . "Force of friction and force of gravity."
- . "Frictional force."

Two (13%) said there was no force on the bike. Only one gave a reason for this answer: "No, force is work done on an object." For the Dip.Ed. sample, 37 (88%) respondents said there was a force on the bike. Reasons included -

- . "Yes, force is force in opposite directions to direction of motion."
- . "Yes, frictional force between the tyres and the road, between the bearings and its support between the bike and rider and the air particles."
- . "Force helps the bike to slow down."

- "Yes, but once started, no force is required for maintenance of movement."
- The remaining 5 (12%) said there was no force on the bike. Reasons given were -
- "No force is applied by the rider. For movement of bike, force should be applied. The bike slows down as the force applied diminishes."
- "Force is required to start movement, but once started no force is required for maintenance of movement."
- "Elimination of external force as in pedalling reduces the force."
- "No, because there is no pressure placed on the bike to either move or stop. It is allowed to move on its own accord."
- "No, force is required to start movement."

CONCEPT OF FRICTION

Drawings were shown of a person on a playground slide in three different conditions - going down the slide and speeding up, going down the slide at a steady speed, stationary on the slide. In each case respondents were asked "Is there any friction between the person and the slide?" Results are shown in table 3.

TABLE 3
Ideas of Friction

Person on Slide	PGDE (N=15) Friction?		Dip.Ed. (N=42) Friction?	
	YES	NO	YES	NO
speeding up	9 (60%)	6 (40%)	37 (88%)	5 (12%)
steady speed	14 (93%)	1 (7%)	42 (100%)	0
stationary	12 (80%)	3 (20%)	42 (100%)	-

Reasons given in the speeding up case:

- "Yes, there is friction between two surfaces of contact." PGDE
- "There must be friction when an object is moving over the other." PGDE
- "Yes, all forces have friction." PGDE
- "He is working against the slide, and there is force between them." PGDE
- "Yes, frictional force opposing his downward motion." PGDE
- "Yes, friction even though very small and reducing prevents the person from falling off the slide." PGDE
- "Yes, speed diminishes the friction." Dip.Ed.
- "Speed increases the friction."
- "No, if there were friction, he won't move fast, there would be some difficulty." PGDE

- . "No, friction occurs before the motion starts." PGDE
- . "No, if there is friction, the sliding would be reduced." PGDE
- . "No, the frictional force has been overcome, hence the fast sliding downward." PGDE
- . "No, there is no movement, therefore the interfaces are not rubbing or interacting." Dip.Ed.

Reasons given in the "steady speed" case:

- . "Two surfaces in contact." PGDE
- . "Yes, sliding force greater than opposing force acting upward." PGDE
- . "Yes, there is some friction because the person is moving slowly." PGDE
- . "Yes, he is rubbing against the slide as he descends. The friction tends to slow him down." PGDE

Reasons given in the "stationary" case:

- . "Yes, the person exerts a force which is opposite to that exerted by the slide." PGDE
- . "There is static friction between bodies not in motion." PGDE
- . "No, no motion, no friction."

CONCEPT OF ELECTRIC CURRENT

There are four questions about electric current. Question 1 is about a touch with three batteries. Respondents have to consider the relative magnitudes of the current in the three batteries. Five options were provided.

- a) No. 1 will have the most current
- b) No. 2 will have the most current
- c) No. 3 will have the most current
- d) Nos. 1 and 3 will have more current than No. 2
- e) They will all have the same current

TABLE 4

Responses in Question 1

Options	PGDE	Dip.Ed.
A	0	0
B	0	0
C	2	2
D	1	0
E	12 (80%)	40 (95%)

Question 2 asks about the existence or non-existence of electric current in an empty light socket. Five options were provided:

- a) No, because there cannot be a current flowing.
- b) Yes, because if you touch it you get a shock.

- c) Yes, because if you put a bulb there it would glow.
- d) Yes, because the current would be going out from the prongs.

TABLE 5

Responses in Question 2

Options	PGDE	Dip.Ed.
A	1 (7%)	29 (69%)
B	5 (33%)	2 (5%)
C	6 (40%)	7 (17%)
D	3 (20%)	4 (10%)

Question 3 explores ideas of the magnitude and direction of electric current in a simple D.C. circuit. Four options were provided.

- a) There is no electric current in wire B.
- b) There is some electric current in wire B but less than in wire A.
- c) There is the same electric current in wire B as in wire A.
- d) There is more electric current in wire B than in wire A.

TABLE 6

Responses in Question 3

Options	PGDE	Dip.Ed.
A	0	2
B	0	7
C	14 (93%)	32 (72%)
D	1	1

Question 4 asks about the existence or otherwise of electric current in a charged battery which is not a circuit.

TABLE 7

Responses in Question 4

Options	PGDE	Dip.Ed.
NO	5 (33%)	35 (83%)
YES	8 (53%)	6 (14%)
No response	2	

CONCEPT OF GRAVITY

Three situations are presented, (standing on the Moon, standing on the earth, falling from a plane) and for each question "Is there any gravity?" is asked. For the moon and falling questions, the magnitude of any gravity is to be compared with gravity at the earth's surface.

TABLE 8

Responses in Question 1 (Standing on the moon)

	PGDE	Dip.Ed.
Yes, but much less than on the earth	2 (13%)	41 (98%)

TABLE 9

Responses in Question 2 (Falling from a plane)

	PGDE	Dip.Ed.
Yes, about the same as on the ground	2 (13%)	30 (71%)

CONCEPT OF LIGHT

Only 33% of the PGDE believe that light travels in a straight line while 69% of the Dip.Ed. believe that light travels in a straight line.

CHEMICAL REACTION

Forty-seven (47%) of PGDE said dissolving of coffee is a chemical reaction while (28%) of Dip.Ed. say it is a chemical reaction.

DISCUSSION

From these results, it is apparent that the two groups have some misconceptions in the selected concepts.

It is surprising that there is no evidence of cultural influences in the responses. The very little differences might be due to orientation and exposure to sophisticated teaching materials. The Dip.Ed. students might have been exposed to lecturers who are very conversant with the Learning in Science Project.

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Research In Science Education, 1986, 16, 82-91.

QUESTIONS ON STUDENTS' QUESTIONS

Hanna J. Arzi and Richard T. White

It is a commonplace observation that learning can be active or passive, but what is less obvious is what actions constitute active learning. Presumably it involves reflection on knowledge, self-monitoring of thinking, and the framing of questions to oneself to check on the quality of learning that one is doing. Attempts to improve students' learning styles might be expected to concentrate on training the participants to ask useful reflective questions, not only overtly as in the course of a lesson, but also covertly when trying to ensure good understanding of recently-acquired knowledge. The investigation reported here is concerned with the latter. It is an exploratory and descriptive study of the types of questions which students in a secondary school generate for themselves in the context of revising for a test.

Specifically, the following issues were explored:

- (1) What sorts of questions do students ask in order to probe their own understanding of a topic in science? What criteria are appropriate for the evaluation of such questions?
- (2) When students are trained in question asking, can outcomes, including transfer of training from one content area to another, be detected in the long-term?

Research on self-questioning has tended to be "content free" (Wong, 1985). Our case study, however, is content related, with a focus on science.

CONTEXT AND METHODS

The study was carried out in a high school in Melbourne. Early in the year, a self-questioning task (Figure 1) was administered to four grade 8 classes (70 students, average age 13). Although students had been told that they could work on the task during the entire period, the actual average time was about 15 minutes.

FIGURE 1

Grade 8 student self-questioning task. (The label "Integrated Studies" in Part 1 refers to integrated history and geography.)

PART 1

One of the topics you covered in last year's classes in Integrated Studies is **THE SETTLEMENT OF MELBOURNE** that is, THE ARRIVAL OF THE FIRST PEOPLE TO PORT PHILLIP BAY.

Suppose you had to prepare for a test on this topic. What questions would you ask yourself before the test, to check whether you really know and understand it? We are interested in the various kinds of questions you may ask yourself, so please write all the questions that come to mind in regard to this topic:

PART 2

One of the topics you covered in last year's classes in Science is **STATES OF MATTER** that is, SOLIDS, LIQUIDS and GASES.

As before (part 1): Suppose you had to prepare for a test on this topic. What questions would you ask yourself before the test, what you really know and understand it?

The students' responses were scanned for preliminary identification of intriguing and puzzling outcomes. These were explored on the next day, through individual interviews with nine students. The interviews (approximately 15 minutes each) were semi-structured, i.e., common stem questions across interviewees were modified and followed up in accord with each one's questions and interview responses. The interviewees were selected on the basis of their questioning tasks, across a range of science achievement levels.

Instruction of all subjects in all classes followed the same syllabi. One of the classes had been previously trained in question asking during the second half of grade 7. This was done along with other strategies intended to instil in the students a metacognitive approach to learning, thus hopefully leading to more effective learning. The training was

interwoven with the instruction of two grade 7 school subjects: English and Integrated Studies. It was done by the two regular teachers of these subjects in this class, as part of a school-based project which involved also other teachers and classes in other year levels (Baird & Mitchell, 1986; White, 1986). Being an action-research project, there were no prescribed training techniques. Hence, the participating teachers made their own decisions as to how to achieve the objectives of the metacognition project during the normal classroom instruction of subject matter.

Our primary interest in the present study was questioning in science, though the student task (Figure 1) referred to an Integrated Studies topic as well. The non-science topic was included to (a) familiarize students with the nature of the task, thus providing a warm-up for questions in science; (b) make a comparative check for content effects that may have been generated by the science topic; and (c) look for long-term transfer of training in question asking from a non-science to a science topic.

FINDINGS ON QUESTIONS AND EVALUATION OF QUESTIONS

Quantity of questions.

Our objectives led us to look for categories of questions and relative frequencies of various question types. Despite our largely qualitative approach, we had to start with a quantitative decision: What is the unit of categorization, and hence of frequency counts? In other words: How to count questions? We had initially regarded question counting as a trivial quantitative activity, but it turned out to be intertwined with non-trivial decisions in regard to quality of questions. For example:

What is the difference between the 3 states of matter? (W03)

What is the difference between Solids & Liquids)

What is the difference between Solids & Gases) (Z07)

What is the difference between Liquids & Gases)

(Student questions are given here and elsewhere without editing, including syntax and spelling mistakes; parentheses enclose student identification codes.) If frequency of questions is an evaluation criterion, is it sensible to count the question of student W03 as one, while those of Z07 are referred to as three? Frequent question asking is probably an educational goal, hence three questions are "better" than one. Yet, the one question in this case seems to be better in terms of its quality, when quality is judged by ability to generalize and to make succinct expressions. At the same time, one may speculate that the one complex question is less likely to lead to a full and well organized answer, than the set of three questions. Hence, in terms of the answers that may follow a given question or set of questions, perhaps the three questions are superior both quantitatively and

qualitatively. These considerations have implications not only for a coherent analysis of research data, but also for guidelines that teachers may advise their students to follow in generating "good" questions.

Problems associated with question counting and evaluation of questions in general, can be further exemplified via the following question: "What gases are flammable [sic]? and why." (W04). Is it one question or two? Similarly to the previously discussed questions, the decision makes a difference when the number of questions is a criterion for evaluation. Furthermore, if this case is counted as one question, it should probably be categorized as a complex question of a reflective nature. Yet, the answer the student may have in mind may reveal that she does not make a clear distinction between the "What" and the "Why" parts of her question, and perhaps mixes facts with reasons or causes. That is to say, before any category label is firmly attached to a given question, congruence between external features of the question and the thoughts and intentions of the student who generated it had better be scrutinized.

Quality versus external features.

The interviews that followed the written questioning task confirm that external features of a given question can indeed be misleading. This was the case, for example, with the following questions:

What are they [solids, liquids and gases] made up of? (W06)

What is a solid made up from? (Y01)

The teaching of the states of matter in grade 7 was in macroscopic terms only, with no reference to the particulate model. We were therefore intrigued by the idea that these self-questions may be manifestations of in-depth probing, and may disclose students' preconceptions on the structure of matter. The following excerpts from the interview transcripts show that this was not the case.

Interview with W06 (I = Interviewer):

I: Why did you ask it ["What are they made up of"]?

W06: I really don't know.

I: What sort of answer would you expect?

W06: [No reply]

I: Did you ever study such a thing?

W06: No.

I: Is it something that really interests you?

W06: Not really.

Interview with Y01:

I: What sort of an answer would you give to question 7 ["What is a solid made up from"]?

- Y01: Umm - same like No. 1 "What is a solid?" Well, explain what a solid is - umm - like - an ice cube is a solid or a liquid, you might have to know that.
- I: And if I gave an answer like "A table is a solid," is it a good answer?
- Y01: No - you have to explain it more - you have to explain why it's a solid Not just like "A solid is something," but explain it a lot, a whole lot of things, a variety of things instead of just one.
- I: I could give such an answer to No. 1, but not to No. 7. What did you have in mind for No. 7?
- Y01: Umm - just - like if someone picked out "A solid is a chair," what is it made up from.
- I: What is it made up from? If you were a teacher, what sort of an answer would you rank highly?
- Y01: Umm - explain it - what a chair is made up from -
- I: Wood?
- Y01: Yeah - or whatever - 'cause it's solid, not a liquid or a gas.

It seems as if the generation of different versions of the question "What are they made up from?" by students W06, Y01 and a few others, followed a common "script" (Schank & Abelson, 1977). It may have started with partial and shallow processing of the information in the task, which led to the realization that the topic is somehow related to materials, and consequently a glib modification of versions of a question type they had frequently encountered in science texts and teacher talk: "What is (fill in the blank) made up from?" Our hypothesis that such a script may have been followed is supported by other cases where, we suspect, students used "standard question stems" which seemed to fit in a science class on materials:

Discovery type questions -

Who discovered gas? (X02)

When where [sic] they discovered? (Z17)

Dangerous chemicals type questions -

What ones can be poisiond [sic]? (W09)

Are they dangerous if exposed to them can we be hurt or injured? (W02)

Can they harm you (Z14)

Use of materials type questions -

What ways can you use solids or liquid or gas? (Y01)

Do they help us in daily life? (W02)

What type of things can you do with solids? (Z01)

What solids & liquids are use ful [sic] to man? (W04)

The possibility that questions are generated via a glib script is worrying.

Our last example of possible discrepancies between surface features of questions and their actual quality refers to inferences drawn on the basis of their initial words. While

words such as "When" and "Where" hint to "low-level" factual questions, "How," "Why" and in particular "What if" are considered to be heralds of "high-level" questions. Yet, this is not always the case, as will be illustrated by the following example (which, obviously, was not taken from the grade 8 student tasks): "When did Thomas Hobbes write Leviathan?" The factual answer is 1651. This seemingly low-level question can be appropriately evaluated only if one considers the context in which it was raised, that is, after reading the following passage from Hobbes' book:

That when a thing lies still, unlesse somewhat els stirre it, it will lye still for ever, is a truth that no man doubts of. But that when a thing is in motion, it will eternally be in motion, unless somewhat els stay it, though the reason be the same, (namely, that nothing can change it selfe,) is not so easily assented to. (Hobbes, 1651, p.4)

The cognitive processing of these lines led the reader to realize that this is actually a statement of what is usually labelled "Newtonian Physics," and consequently to wonder whether Hobbes could have been exposed to it when he wrote Leviathan. The answer is negative, since Newton was nine years old at the time, which leads to further reflection on Newton's much quoted observation of standing on the shoulders of giants. The case of Newton and Hobbes is, of course, not an issue in our paper. The point we wish to make is that a "When" question can be involved with extensive cognitive processing. Hence, labelling of questions as high or low level, on the basis of initial question words or other surface features, should be done with circumspection.

Our reservations in regard to meaningful evaluation of quality of student questioning reflect the problematic issue of how one goes about defining quality to start with (Pirsig, 1974). Nevertheless, we believe that research on student questions can and should be performed, despite awareness of its limitations.

FINDINGS ON QUESTIONS AND TRAINING IN QUESTIONING

Having realized that the validity of any sort of "exact" counts and categorization of questions would be questionable, we decided that rough estimates would suffice to gain a "feel" for student questions. Counting was done according to the way students seemed to separate unit questions from each other. This was simple in most cases, since students usually numbered their lists. In other cases, the counting followed cues, such as question marks or question words ("When," "Where," etc.). Two coarse-grained classifications were performed, one concerned with the seemingly cognitive level of questions, the other with their topic-content relatedness.

Fluency and content.

The total number of questions was lower in the science topic than the non-science one (Table 1). The explanations given in interviews for the relative number of questions were in terms of liking for, and ease of learning and retention of topics, and the extent to

which a topic lends itself to question asking. For example: "Because I remembered that more, because I like doing that better than that If you like it you usually remember it more so you can write more questions about it." (W15).⁶

Since the task required students to refer to topics they had studied in the previous year, one could expect a retention effect. However, having no independent measures of immediate and delayed recall in both topics, and no comparative information on learning and questioning in other topics in science and integrated history-geography, we cannot draw conclusions on the relative contributions of different factors to questioning fluency. In any case, content obviously matters. Hence, a content-free approach to research on student questions does not seem to be justified.

Cognitive processing and awareness.

A given question was classified in the "high cognitive level" category if any of its surface features were suspected as being involved with cognitive processing beyond simple recall of discrete entities of information. Despite this permissive classification criterion, the percentage of seemingly high-level questions was small in both topics. Time for reflection on task was amply available. The post-task interview request to scan the work and point to "good" versus "not so good" questions was encountered with silence, "I don't know," "All are the same," or hesitant explanations. Our impression was that awareness of cognitive processing was generally lacking, and that reflection via questioning was an unfamiliar notion. The interviewees made us realize that many student questions were not self-generated. Rather, students tried to recall teacher and textbook questions: "I tried to put my own questions 'cause I couldn't remember more." (W15).

From students' oral comments during the administration of the task, their written comments in the work, and the interviews, it became clear to us that experience in reflective self-questioning prior to tests was limited (if not absent): "But I ask myself no questions, I just read the book!" (oral comment); "I usually read over my book or I get my mum to read out questions and I answer them." (X15). Consequently, we have to criticize ourselves for attempting to evaluate student self-questioning through a task referring to a situation which is normally not involved with self-questioning, and is unlikely to elicit "high cognitive level" questions. Nonetheless, the findings that revisions for tests are not usually involved with reflective self-questioning should cause concern. The results presented thus far, and those that follow, lead us to believe that our tentative conclusions on students' limited awareness of their thinking and their inclination to be satisfied by shallow information processing are, unfortunately, valid in other situations as well.

TABLE 1

Mean number of questions per student and percentage of content-related vs. general/test-related questions, on two topics in a self-questioning task for grade 8 classes, with and without grade 7 training in questioning.

Class	n	States of Matter		Topic Settlement of Melbourne	
		Mean Number of Questions	% Content/% General Questions Questions	Mean Number of Questions	% Content/% General Questions Questions
1 Untrained	19	5.9	82/18	7.7	85/15
2 Untrained	18	2.9	81/19	3.6	87/13
3 Untrained	18	5.0	100/ 0	7.2	99/ 1
4 Trained	15	4.2	63/37	5.1	54/46

Training for questioning.

Although both parts of the task dealt deliberately and explicitly with specific topics, not all the student questions did (Table 1). Almost all those that did not, used general terms referring to learning for tests. For example:

Do I understand everything. / Did I study enough / How long will the test be / If I fail, would I be the only one who didn't pass (W05)

What will happen if I get low marks (W18)

Should I know more about it or do I already know all there is to know. / Where did I need to get the information? / Have I studied my hardest? (Y15)

Was this thing important to remember or not? / Must I remember every single detail (Y14).

Apparently, the non-content-related questions and the task share a common context, that is, all refer to hypothetical tests. It is also true that some of these questions are

important to ask, and students who posed them may therefore be labelled as having a "metacognitive approach" to learning. Yet, none of these questions is congruent with the task, since they do not probe directly for knowledge and understanding of the topics in point. Hence, we doubt the extent to which their generation was involved with conscious cognitive processing. If, for example, student Y03 had acted upon her own questions, she would have probably not included them in her work, to start with: "Have you read through the test? Does it make sence [sic]? Do you understand the questions?"

The percentage of seemingly metacognitive questions was particularly high in the class which was trained in questioning and other metacognitive strategies (Table 1). This was the only finding that stood out in our analysis as a training outcome. In view of the above criticism, it is disappointing. But at the same time, the fact that training in grade 7 had visible outcomes in grade 8 should not be taken for granted. Furthermore, this is clearly a case of long-term transfer, since the training which had originally been only in English and Integrated Studies (including the topic Settlement of Melbourne), was manifested in a science topic. We believe that careful long-term training which accentuates the interplay between "good" questions and thinking processes, may diminish the risk of question asking becoming trivialised and routine.

Lastly, we wish to emphasise that our present study treated the case of training in questioning as a discrete event, out of its context. That is, to evaluate it appropriately, one has to consider the entire metacognition project that the students were part of, which has demonstrated encouraging results (Baird & Mitchell, 1986).

LAST COMMENTS

The assumption that set off the present paper was that engaging students in questioning may increase their active cognitive involvement in school learning. Our exploratory study on self-questioning actually added new concerns to our initial ones. Firstly, we found severe problems in establishing criteria for the evaluation of questions, and we consequently doubt whether "neat" studies on that matter can be done. Secondly, we realized that the fact that students are questioning does not necessarily mean that they are actively engaged in thinking: Even after training in metacognition, glib questions may still prevail. Despite all this, we believe that awareness of these problems can be a promising starting point for both researchers and teachers. Apparently, it is impossible to define quality of questions (or of anything else) in general terms. Yet, it is possible and desirable to provide teachers with research-based sets of working criteria which they can then modify for guiding their students. To do this, classroom research needs to be done on training in questioning and the cognitive processes that underlie the production of different types of questions in particular content areas and contexts.

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Research In Science Education, 1986, 16, 92-100.

LESSONS FROM SCIENCE EDUCATION IN THAILAND:
A CASE STUDY OF GENDER AND LEARNING IN THE PHYSICAL SCIENCES

Peter Fensham

By the later 1970s, the science curriculum movement that began around 1960 in a spectacular way in the USA (with the NSF projects) and in Britain (with the Nuffield projects) had spread to many countries. Indeed, deliberate reform and new developments in the science curriculum had occurred in more developing (or less industrialised) countries than in developed (or highly industrialised) ones. This was a consequence of the tremendous momentum of that reform movement, the importance of science in all societies and the fact that there are more developing countries than developed ones.

Accordingly, in the later 1980s there is now in existence a very wide range of experience of attempts to implement new curriculum for science education in schools. A number of the early attempts in developing countries were implementations of curricula (and materials) which had been developed for the school systems of another country often with very different social, cultural, economic, and political characteristics. However, by the later 1960s and the 1970s many developing countries had embarked upon their own reform and development, and were implementing their own new science curricula, albeit with varying degrees of influence from the experiences of the earlier projects and their implementation.

The time sequence of these events has meant that at least some developing countries have been in a very advantageous position about these curriculum tasks. That is, they have been able to learn much from the experience of others and to build features into their curriculum projects that were intended to avoid demonstrated pitfalls.

A number of sources of this "experience of others" have been available to a number of the persons who have been responsible for these new science curricula. There is the internationally available, published literature in journals and books that report developments, evaluations and research in science education. There are conferences, international and regional, that enable science educators from different countries to hear

from and interact with each other. There are international documents and resources of the type produced by UNESCO and related or similar international agencies. There are study tours that enable the responsible persons in one developing country to visit other countries. Finally, a significant number of the staff in some of the developing world's projects have done higher degrees in countries like Britain, USA, Australia or Canada.

Somewhat surprisingly, a number of these sources turn out to be much more available to the curriculum developers in developing countries than they are to those in the more developed countries. The great majority of the articles and reports in the commonly available science teacher education journals and in the few research journals are about science education in the more developed countries. Science educators in smaller developed countries like Australia and New Zealand regularly have access to and read all the English language journals from Britain, the USA and Europe as well as their own national journals. However, this is not the case in the USA and Britain where there is a tendency for science educators to have available, and hence to read, only that country's own journals. Two pieces of evidence for this is the absence, in the libraries of quite leading universities in the USA and Britain, of journals from foreign countries and the range of references cited by authors from these countries in their papers.

Only occasionally, through the journal sources available to them, will science educators in the developed world read of the experiences occurring in the less developed world. Although overseas journals are a currency exchange problem for many developing countries, it is not uncommon to find some of these journals in their curriculum project offices and in their leading universities.

Science educators from developed countries do participate in international conferences but mainly to hear each other talk and again, only much more rarely do they hear key note speakers or major papers from developing countries. Because of the nature of UNESCO's regions only science educators from Australia, Japan and New Zealand, among OECD countries, regularly hear reports of science education in the developing countries. UNESCO type documents are more accessible in developing countries, and study tours and higher degree studies abroad are not common phenomena among science educators in developed countries. When they do occur they almost never involve visits to developing countries.

Thailand is a developing country that has put a great deal of effort into science education for its schools since 1970. A national centre was established, the Institute for Promotion of Science Teaching (IPST), in Bangkok. The work and methods of curriculum development of this remarkable centre has been reported in a number of places (UNESCO [1984] and White and Butts [1975]) but not as yet to my knowledge in detail in the British, American or European science education literature. A succession of curriculum

development projects have been undertaken by the staff of the Institute so that by the mid 1980s new curricula (some revised already) were in place at every level of the Thai schooling system.

This system is indicated schematically in Box 1.

BOX 1

The structure of schooling in Thailand and its organization of science curricula.

		Vocational schools (Broad vocational streams)	Academic schools	
			(Science stream)	(Humanities stream)
Upper secondary schooling	3	Specially designed science courses for each stream	Physics	Physical
	2		Chemistry	science
	1		Biology	
Lower secondary schooling	3		(All pupils)	
	2		General Science	
	1			
Primary schooling	6		(All pupils)	
	5			
	4			
	3			
	2			
	1	Life experiences (including science)		

For each sector in the system as shown in Box 1, there is a specially designed curriculum so that students in all these sectors study science. This organisation of science education is an example of a SCIENCE FOR ALL that is still only a vision splendid or a current day challenge to the science educators in most developed countries (Fensham [1985]).

Australian science education has been most fortunate in that a number of its leaders have had the opportunity to work closely with the Thai teams at IPST. Accordingly we are much more informed (though still all too inadequately) than are science educators in other developed countries about the Thai experience of science education. Whether or not we are able to learn from it is a much more complex question and it is in fact the subject of this paper. Some very exciting and recent Thai research findings are used as exemplars.

There is no doubt that we in Australia expect to learn and be influenced by the experience of science education in countries like USA, Britain, Germany, New Zealand. I am not so sure we expect to learn from Thailand or Sri Lanka or the Philipines. In successive years I have recently tried to report the achievements of Thai science education at conferences in the USA and been struck by the dismissive incredulity of a

number in the audience. I hope Australia's appreciation of its place in Asia has reached a point where its science educators are not so arrogant and dismissive. Nevertheless there are such major cultural differences that even a willing attitude will still find it hard to know what to learn from results like the following:

GENDER AND SCIENCE LEARNING IN THAILAND

Sunee Klainin (1985) in a very elegant doctoral study investigated the learning achievements in chemistry of girls and boys in the three final years of the Thai system (Years 10, 10 and 12). The subjects of her study were 714 boys and 767 girls and they were in single sex schools and co-educational ones. The learning was assessed by means of 7 sets of tests covering aspects of practical or laboratory learning (10 sub-tests), a number of different features of theoretical or content learning (10 sub-tests) and the students' attitudes to science (1 test).

The study and its results have been reported elsewhere (Klainin [1984] and Klainin and Fensham [1987]). In summary it was found that girls significantly out-scored boys in six of these tests and in the seventh (concerned with observations of chemical changes in the laboratory), there was no significant difference between the two sexes. The girls in the single sex schools, in general, were the highest achievers followed by the girls in co-education, followed by the boys in co-education, and then the boys in single sex schools. These results are not consistent with most of the reported studies on chemistry learning from developed countries (see, for example, Kelly [1981]) which have reported a bias of success towards boys.

In a subsequent study, Klainin established that biology is seen by more than 70% of both boys and girls in Thailand as being a subject more suited for girls. Physics, in contrast, was perceived by more than 95% of both sexes to be more suited for boys. These results (Klainin and Fensham [1987a]) are very similar to the position that has been repeatedly reported in developed countries. The Thai perception of chemistry turned out to be interestingly different however; more than 65% of both sexes seeing it as appropriate for both sexes to learn.

As part of this second study Klainin also used an instrument that helped her to understand some sources for these perceptions. As far as I know no similar instruments have yet been used in more developed countries.

A parallel study to the chemistry one in physics was an obvious next piece of research, and Klainin began this very large task (in terms of its data collection) in the second half of 1985. This new study was important, both because of its intrinsic interest for the Thai system and because it is girls' achievement of physics learning (much more

than chemistry) that epitomises the bias against girls in the science education of so many industrialised countries.

Indeed, when the chemistry findings were presented at AERA in San Francisco in April 1986, the significance of the more positive performance by girls than in any other country's report was avoided in the discussion that followed because a similar finding for physics was not available!

These gender findings result from a major feature of the design of Sunee Klainin's studies but they are only a part of it. Overall her studies are an evaluation (on an unusually broad scale) of the new Thai science curricula in chemistry and physics including their particular emphasis on the role of practical work. It was intended (as part of a joint study being undertaken between IPST, Dr Leo West and myself) that Sunee Klainin would be at ASERA in May 1986 to present several aspects of her work. This would have been most appropriate as her original design was presented at ASERA in 1984 when she was a student at Monash.

Alas, a few weeks before the ASERA conference in May 1986 we learnt that Sunee was unable to come - a rather stark reminder again of the bias against third world researchers for whom funds for research conference travel are so much harder to get. On my own arrival at the conference, at what for so many of us is an easy annual pilgrimage, I found that the basic gender results from the physics study had just arrived by mail to ASERA!!

In the 5 sets of tests (involving 17 measures or sub-measures) used in this study girls significantly outscored boys on 7 of the measures and on the remaining 8 there was no significant difference between the girls and boys mean scores.

Accordingly, the ASERA community has now no excuses for avoiding the question, What can and should we learn from the science education experiences and research findings of Thailand?

We are no longer in the state of ignorance that is the lot of so many science educators in the developed world. These studies from Thailand provide us with models for curriculum evaluation that have not, to my knowledge, been so extensively applied elsewhere. They also include a number of new research instruments. Finally they have yielded results that provide new insight and new hope for a number of very general curriculum concerns in science education (Klainin, West and Fensham [1985]).

Accordingly, in the remainder of this paper I wish to begin a discussion which does attempt to take the gender aspects of these results seriously.

DISCUSSION

The findings for the learning of girls in physics and chemistry in Thailand are remarkable because they are different in a very positive direction from the findings that

have been of such a concern in a number of other countries where girls, in general, not only participate less in these subjects than boys but also achieve less well.

If we are to learn from the success of the Thai system with these girls in the physical sciences we may first need to suggest explanations for it.

At the very least they can be said to squash the idea that is raised in the literature (e.g. Hacker [1986]) that a biological factor may be significant in the better performances of boys in these levels of learning science.

For western countries, Manthorpe (1982) and Kelly (1981b) have collected together a number of social factors suggested as contributing to a bias in favour of boys. The first is the organisation of schooling and the timetable which can make some subjects less available to girls. The second is, in fact, an umbrella of factors under the broad title of teaching approaches. Included are the sorts of skills that are assumed or involved in the teaching of science, textbooks which overtly or subtly imply that these subjects are for males (Taylor, 1980; Walford, 1980), the design of examination items (Harding, 1977), and the relative lack of involvement of girls in science lessons in co-educational classes because of the attitudes of teachers (most of whom are male) and of peers. The third is the flow into schools of family and societal attitudes which deter girls from choosing to study physics and chemistry. Finally, science itself (and particularly, the physical sciences) are said to have a masculine image that, in a number of ways, is a deterrent to girls at a time in adolescence when they are forming conceptions about female identity and feminism.

It is useful to relate the Thai studies to these suggested factors. In the first place, the organisation of schooling and of the curriculum and its timetable in Thailand has a number of features that are very different from many western countries. Boys and girls, entering the upper levels (Years 10, 11 and 12) of secondary education have to declare their intentions to study in the "science" or "humanities" areas and they then continue to this chosen area for three years with very few dropping out. Those who choose the "science" area have to study biology, chemistry and physics in each year. Those who choose the "humanities" are required to take at least two years of specially designed science study based on biological and physical sciences.

These organisational features of schooling are important and they relate also to the third set of factors above. That is, they seem to avoid, for Thailand in this stage of its development of secondary education, the very serious school and social problems in many western countries where female students are either not choosing to study the sciences at all in these senior secondary levels or are opting for biology alone rather than any of the physical sciences. Indeed, a great amount of the present curriculum effort in these countries concerning girls and science education is focussed on how to affect these choices of girls and how to entice them into physics and chemistry.

With respect to the second set of factors, the teaching approaches in Thailand present a mixed appearance in relation to those in western countries. The classroom content, laboratory exercises and the text books do not seem to be very different from those advocated by many other recent chemistry or physics courses. Certainly, the teaching materials and student texts have not been made gender inclusive in the directions that some curricular groups in western countries are now exploring.

In practice, at least in Bangkok, the recommended practical work in the laboratory of the IPST course may be more regularly observed (about two-fifths of the time per week, according to Klainin, 1984) than in countries like Australia and the USA, but it would not exceed the proportion of practical experience obtained by some European students (Fensham, 1980).

Several other aspects of the teaching practice in Thailand are, however, different. Eighty percent of chemistry teachers are women but in physics the sex balance is more like fifty percent. The curriculum development team at IPST for chemistry was almost entirely female, including six of its seven leaders over the years. The physics team, on the other hand, has been mainly male. The centralisation of curriculum in Thailand also means that the influences, whatever they are, of these teams of persons and their products do tend more quickly to make a mark in all the schools of the country than has been the case with the new science curricula in many western countries.

In the course of her studies of chemistry, Klainin observed twelve co-educational classrooms, and found that, in general, the girls sit in the front half of the class and probably are more dominant in the classroom verbal interactions. This pattern would appear to be very different from what has been reported in a number of these sorts of studies elsewhere.

Only a little can be said from this research evidence about the image of the sciences in Thailand, the fourth set of factors above. Chemistry does seem to be more associated with activities that are seen as appropriate for women than would be the case in western countries and this may be the result of links with activities and roles in the household. Physics on the other hand seems to be seen in Thailand as "male-appropriate" in much the same way that it is in western countries.

This discussion has outlined a number of contextual aspects of the Thai school system and several student perceptions that may be related to the successful learning of physics and chemistry by girls in that country. Some of these aspects are similar to those in western countries such as the perceptions that physics and its laboratory activities are more appropriate for boys, and the content for learning and the curriculum materials in the two subjects. A number of other aspects are rather different. Some of the differences are no doubt culturally associated with Thai society and hence are not

transferable. Others are not so culturally tied and it is presumably these we should set out to identify and then try to implement in the Australian scene. For example, one of the quickest ways to begin to shift present biases in Australia and other western countries would be to change the organisation of schooling so that all girls and boys are required to study physics, chemistry and biology, as in Thailand. If more girls are in these classes some at least would succeed. This would also have the advantage that it would then be possible to distinguish between factors that are, at present, important for enrolment, like the images of science and the match between traditional skills in science teaching and the existing confidences of girls, and those which are important for achieving successful learning. Unfortunately, in many societies like Australia, Britain and the USA, making physics and chemistry compulsory for all girls and boys is probably politically very difficult. Schools in these countries are very largely concerned with reproducing cultural values and the inequalities and the biases in the society outside. Choice is an important cultural value and hence girls and good science education are some of the losers in these reproduction processes, just as they are in the wider societies.

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Research In Science Education, 1986, 16, 101-110.

CONDITIONS OF LEARNING IN SCIENCE CLASSROOMS AND WHAT WE CAN LEARN FROM THEM*

Miriam Ben-Peretz and Joseph Menis

Conditions of learning set the stage for the phenomenon of learning, they constitute the context in which learning is anticipated. This context is conceived as shaping the learning process. Conditions of learning may be defined as "sets of circumstances that obtain when learning occurs" (Gagne, 1970, p. 3). One way of looking at any phenomenon, and the conditions that obtain when it occurs, is to use a language of indispensable requirements. Educational research has attempted to investigate the conditions of learning in the sense of indispensable requirements. Research on "time on task" is an example of such inquiry (Fisher & Berliner, 1985).

In this paper "conditions of learning" are employed in a different sense. Conditions of learning are defined as the contextual circumstances that obtain when learning is anticipated, the situational components and events which constitute any concrete and observable context in which learning is assumed to take place. The main objective of this paper is to describe and analyze some of the situational components and events which occur in the reality of science classes, whether these lead to predetermined outcomes of learning or not. Knowledge about the practice of science teaching is deemed to be a necessary prerequisite for any attempts to introduce innovations and improvements (Schwab, 1970). Insights into concrete learning environments may ultimately lead to a better understanding of causal links in the process of teaching and learning science.

CONCEPTUAL FRAMEWORK

The quest for conditions of learning is guided by the following questions:

1. What are the organizational arrangements for learning? More specifically, what are the circumstances of learning, such as the size of the learning group and the amount of teacher supervision (Harnischfeger & Wiley, 1976).

* The study upon which this paper is based was funded by a grant from the Social Sciences and Humanities Research Council of Canada.

2. What are the ecological features of the learning environment? (Doyle, 1977). The ecological environment is viewed as pertaining to two components: a) the physical environment and b) the social environment.
3. What are the roles of teachers and students in the learning process? Are teachers functioning as sources of knowledge, or, as resource persons, assisting students in their own, active, search for knowledge? (Schwab, 1960; Sutton & Haysom, 1974).
4. What teaching strategies are adopted by the teachers? Teaching strategies are conceived as pertaining to structure of lessons, to modes of laboratory work, modes of explanation, use of out of school resources and linking of school knowledge to life situations (Head, 1974).

This is not a comprehensive and full agenda of questions which may form the conceptual framework guiding research of conditions of learning in science classes. Important issues, such as the nature of participating learners and teachers, are not treated in this framework, though the knowledge, attitudes and skills of learners and teachers constitute integral components of the context in which learning is assumed to occur. The complexities of the learning context are enormous and it is deemed necessary to focus on parts before attempting to integrate the composite whole.

METHOD

The data base for this paper was collected in the frame of the Second International Science Study (SISS) in Canada, under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). The focus of the study was upon the teaching and learning of science at three levels: grade 5, grade 9, and grade 12 (grade 13 in Ontario). The samples at each level contained schools, teachers and students from each of the Western, Central and Eastern regions of Canada. The first phase of the study was an extensive curriculum analysis of science education in Canada, the results of which are contained in Connelly et al., 1985. The second phase involved achievement testing of students at the end of their science courses, as well as teacher questionnaires providing information as to whether the content covered by the achievement items had been taught by them. In a special questionnaire students described the instructional approaches of their teachers. Statements included in this questionnaire are presented in Appendix 1. It is contended that these statements provide at least partial answers to the questions posed above.

It should be noted that this paper deals with conditions of learning as perceived by students in science classes and does not include corroborative evidence collected through classroom observations.

POPULATION

Data was gathered from students in science classes who responded to the Senior Secondary level questionnaire. Three optional responses for each item were: 1 - often, 2 - sometimes, 3 - never. The population consisted of 576 science classes broken up into subject matter areas as follows: 202 biology, 187 chemistry, 187 physics classes. The data was aggregated at class level, creating a mean response score for each item for the students within each class. A lower mean signifies a higher prevalence of the instructional approach indicated by the item. Factor analysis was carried out and linear relationships of factors and variables with student achievement in each subject matter were examined by Pearson correlations. Overall class average on the tests in biology, chemistry and physics served as achievement data.

The large number of classes is conceived as the basis for providing a valid picture of the reality of conditions of learning in science classes.

FINDINGS

We shall turn first to the national means of responses to each item in the instructional approaches questionnaires (see Table 1 and Appendix 1).

Several instructional approaches emerge as most prevalent, while others are much less common. Use of textbooks (item No. 1) and tests (item No. 14), as well as heavy reliance on teachers' direct instructions (item No. 20), or text instructions in laboratory activities (item No. 21), seem to be the ruling conditions that obtain in learning science. Students also report that laboratory work is an integral part of their experience in science classes (item No. 18). The most prevalent conditions of learning are the most traditional. Teachers and textbooks are the main sources of knowledge, and students are habitually evaluated by tests. Still, the enlarging picture is not onesided, group work constitutes an integral part of science classes and teachers seem to create an atmosphere of support for students who experience difficulties.

On the other hand, teachers tend not to use books, other than textbooks, for learning science (item No. 2) and there is hardly any fieldwork, carried out outside the classroom. The least prevalent conditions of learning science, as experienced by students, are opportunities for independent inquiry (items 23 and 24), teachers' use of students' ideas in lesson planning (item 7), fieldwork (item 17), and creating an atmosphere of relevance of science to the future work of students (item 13). It seems that some of the most important suggestions for teaching science, such as self-guided inquiry and relevance, have not found their way into science classes (Goodlad, 1984).

Interesting significant differences emerge in the different subject matter areas. Relevance of the subject matter to everyday life is stressed more in biology classes (item No. 12). On the other hand, students in chemistry and physics classes write up more laboratory reports as part of their homework (item No. 11). Calculators are used more in chemistry and physics classes than in biology classes (item No. 16). Students who learn chemistry perceive their teachers to be more helpful in case of difficulties (item No. 15), than students in the other subject matter areas.

TABLE 1
INSTRUCTIONAL APPROACHES
(National Means by Subject Matter)

Statement	Biology	Chemistry	Physics
1	1.39	1.35	1.33
2	2.22	2.26	2.28
3	1.63	1.69	1.66
4 **	1.72	1.83	1.79
5 **	2.09	2.18	2.10
6	2.46	2.46	2.40
7 **	2.56	2.59	2.51
8 *	1.66	1.55	1.52
9	1.69	1.72	1.74
10	1.50	1.47	1.45
11 *	1.79	1.66	1.66
12 *	1.82	1.93	1.90
13	2.32	2.32	2.27
14	1.08	1.07	1.09
15 *	1.52	1.39	1.44
16 *	1.93	1.22	1.18
17 *	2.59	2.73	2.63
18 **	1.56	1.47	1.52
19 **	1.33	1.24	1.28
20 **	1.21	1.22	1.26
21 **	1.42	1.33	1.38
22	2.76	2.79	2.75
23 **	1.98	1.88	2.04
24 **	2.75	2.79	2.27

Scale 1 - often, 2 - sometimes, 3 - never, * $p < 0.001$, ** $p < 0.005$

The nature of students' experiences in science classes, and the perceived differences between disciplines, may partially determine students' inclination to choose scientific fields of study. Factor analysis yielded 7 factors as presented in Table 2.

These factors were identified as representing the following themes: Factor No. 1 - Laboratory work, factor No. 2 - Clarity of teachers' instructions, factor No. 3 - Student centered teaching, factor No. 4 - Student originated learning, factor No. 5 - Use of resources, factor No. 6 - Teacher centered teaching, factor No. 7 - Assessment and quantification.

TABLE 2
FACTOR LOADING OF TEACHERS INSTRUCTIONAL APPROACHES

Item	FACTORS						
	1	2	3	4	5	6	7
11	75						
18	88						
10	82						
21	63						
.....							
3		77					
4		72					
5		74					
20		44					
.....							
7			47				
8			62				
9			53				
12			59				
13			69				
15			58				
.....							
22				84			
24				83			
.....							
1					57		
2					70		
17					61		
.....							
10						70	
23						47	
.....							
6							63
14							56
16							47

Note: decimals omitted

Factor	Eigenvalue	% variance	cummulative % variance
1	4.45	18.5	18.5
2	2.73	11.4	29.9
3	2.13	8.9	38.8
4	1.40	5.8	44.6
5	1.34	5.6	50.2
6	1.20	5.0	55.2
7	1.06	4.4	59.7

How do these empirically determined factors relate to the research questions posed above? Factor 1 (laboratory work) and factor 2 (clarity of teachers' instructions) and factor 7 (assessment and quantification), pertain to the first question about organizational arrangements in science classes, representing modes of organizing learning groups and

supervising the learning of students. The ecological features of the learning environment, the physical and social context of learning, find their partial expression in factor 3 (student centered teaching) and factor 5 (use of resources). Factor 3 speaks directly to issues of the social environment. Factors 4 (student originated learning) and 6 (teacher centered teaching) relate to issues of the respective roles of teachers and students in the learning process.

What is the impact of the factors, elicited in the study, on one important measure of learning science, namely, on achievement?

Table 3 presents correlations between factors and achievement in various subsets of achievement tests for each subject matter area.

Factor 1, laboratory work, shows negative correlation with several of the subsets of items in the chemistry test, and no correlation with achievement in physics. Because the coding of items, negative correlations are to be interpreted as signifying that the more prevalent a factor is the higher the achievement on the test. It is not surprising that laboratory work, as part of the learning conditions in chemistry, is correlated with higher achievement in a number of subsets of test items. Factor 2, clarity of teachers' instructions, is correlated mainly with achievement in biology subsets of test items. It may be that the complexity of biological phenomena necessitates more direct and clear instructions of teachers. Factor 3, student centered teaching is correlated with achievement in biology and chemistry. This factor reflects learning conditions which create a supportive class climate and seem to provide a learning environment which is responsive to students' needs. It is interesting to note that factors 1, 2 and 3 do not correlate with achievement in physics. It seems that requirements for learning conditions in physics are distinctly different from those in biology and chemistry. Factor 4, student originated learning, correlates with achievement in all subject matter areas, but, the correlation is to be interpreted in a converse manner. The more emphasis on self-originated learning, as part of the conditions of learning, the lower the achievement. It may be that the ways in which students are encouraged to be more autonomous in their learning are inappropriate. Factor 5, use of resources, textbooks, other books and field work correlates conversely with achievement in physics. Apparently the manner in which these resources are used is not very conducive to the learning of physics. Factor 6, teacher centered teaching, correlates with achievement in subsets of items on the physics test. It seems that these teaching activities create conditions that favour learning. Factor 7, assessment and quantification are correlated differentially with achievement in biology and chemistry. The subject matter differences of correlations of factors that determine conditions of learning with achievement are intriguing and call for further investigations, such as in depth classroom observations.

TABLE 3
Correlations between factors of instructional approaches and
achievement, in subsets, in each subject matter area

Factors-----	Biology subsets						Physics subsets						Chemistry subsets								
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9
1			-24										-17		-20		-29				
2			20	19		19									17						
3			-27-25		-14	-16-24									-23		-24	-16	-28		-25
4					14	16				24									14	-19	
5							37				20				-20						
6						-15	-28	-19													
7			-17			-20									19	16					

Note: decimals omitted

p < 0.05

DISCUSSION AND CONCLUSIONS

Conditions of learning that were found to obtain in science classes in this study are mainly in line with traditional orientations and practices. Teachers use mostly textbooks as sources of knowledge. Lessons are structured by teachers who tend to direct the learning process, using strategies such as summarizing or having students copy notes from

the blackboard. Testing follows instruction with relentless regularity. There are few opportunities for self-directed inquiry and, even more important, the relevance of science to students and their future lives is hardly ever part of the teaching of science. Science teaching almost always takes place in classrooms only. Out of school resources are seldom used. Thus, conditions of learning science are restricted to the classroom environment and the full potential of field trips, for instance, which provide different conditions for learning biology, chemistry and physics, is not realized.

Conditions of learning in the realm of personal interaction are perceived positively by students. Laboratory work is part of the context of learning science, as are experiences of group work. In this sense the reality of science classes sets the scene for more openness to differentiated needs and inclinations of student groups. Yet, little of this happens. Only rarely do students experience opportunities of self-directed learning and their wishes and concerns are seldom considered. The gap between school and life is not narrowed. A supportive atmosphere, group work and shared laboratory experiences are not enough. In order to create conditions for learning science that allow for more active involvement of students in the learning process, and for more openness to societal concerns, teachers have to change their own instructional approaches. This is a highly problematic issue. Cuban (1984) documents the traditionalism of American teachers whose teaching does not change over time. Doyle and Ponder (1977) comment on the "practicality ethic" of teachers which prevents teachers from making decisions and introducing changes which they deem to be impractical. It may well be that the nature of the structure and organization of science classes has to change radically and drastically in order to create conditions for a different mode of learning science. One can imagine science teaching which will integrate different formats and structures in a way that will preclude the prevailing of traditional conditions of learning. Such a design of science teaching could include lectures before large groups of students, followed by small group tutoring and guided field work geared to problem solving in real life contexts, such as farms, hospitals or factories. These learning experiences could be handled individually, or in teams. Reports on fieldwork would partially replace paper and pen tests. There would be fewer opportunities for copying notes from blackboards, or for summarizing lessons for students. Conditions of learning science would thus change dramatically. It is obviously difficult to predict possible outcomes of such changes. Yet, the results of learning science under present conditions are not very satisfactory - it seems worthwhile to try to create different conditions.

There are commonalities in the conditions of learning different subject matter areas in science. Still, the emerging differences are interesting and may have far reaching consequences for students. Relevance of subject matter to every day life characterizes

conditions of learning in biology classes. Is this because biology is, indeed, more relevant to human life? This seems hardly to be the case. After Chernobyl and the dangers of chemical pollution, physics and chemistry are certainly equally "relevant" topics of study. It is contended that physics and chemistry teaching will have to change in order to attract students who search for learning conditions which will help them see the relevance of the pursuit of science to their own lives.

We need to know more about the practice of science teaching, about conditions of learning "behind the classroom door". Insights can be gleaned from students' perceptions, as in this study, but these are not enough. Careful and patient classroom observations and inquiry into teachers' thinking about science teaching, are needed to complement the picture.

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APPENDIX 1

Instructional Approaches Questionnaire Items

1. We use a textbook during science class.
2. We use books other than textbooks for learning science.
3. At the start of each science class the teacher reminds us about the work we covered during previous classes.
4. At the start of each science class the teacher explains the work we have to cover during the class.
5. At the end of each science class the teacher gives a summary of what was taught in the class.
6. We are allowed to make our own choice of science topics to study.
7. The teacher uses our ideas and suggestions when planning science classes.
8. The teacher does demonstrations to help explain scientific ideas.
9. The teacher makes science classes interesting for us.
10. During science classes we copy the teacher's notes from the blackboard into our own books.
11. For science homework we write up reports of our laboratory and practical work.
12. The teacher explains how the science we learn is relevant to our lives.
13. The teacher discusses possible careers in science with us.
14. We have tests on what we have learned in science.
15. The science teacher helps students who have difficulties with learning science.
16. We use calculators during science class.
17. We do field work outside the classroom as part of our science classes.
18. We do laboratory work as a part of our science classes.
19. The science class breaks into small groups of students to do laboratory work.
20. When we do laboratory work, the teacher gives us instructions about what to do.
21. When we do laboratory or field work, we use a book or other written instructions to show us how to do it.
22. In our laboratory or field work we make up our own problems and then the teacher helps us to plan experiments to solve them.
23. When we do laboratory or field work the teacher gives us problems to solve and then leaves us to work out our own methods and solutions.
24. In our laboratory or field work we make up our own problems and work out our own methods to investigate the problem.

Research In Science Education, 1986, 16, 111-118.

CONSTRUCTS USED BY SCIENCE TEACHERS TO DESCRIBE
ABLE STUDENTS: A PILOT STUDY

John Bailey, Colin Boylan,
Rodney Francis and Doug Hill

Little work has been done on identifying the constructs which science teachers use to describe students with an excellent grasp of and aptitude for science. This is not surprising since Blurton (1983) has argued that whilst science talent is something we might agree exists, it is difficult to identify. Nevertheless teachers do develop their own constructs and use them as a basis for making decisions. These constructs are seldom made explicit and thus go unchallenged.

According to Kelly (1955) personal constructs are important in all our daily transactions. Each person constructs their own framework of reality by a process that includes what they bring to each situation or event and how they process the observations drawn from that situation or event. This notion is particularly useful when examining classroom practice. The constructs which science teachers hold mediate in classroom decision-making (Hill, 1985). Teachers' ideas about the nature of science and the attributes needed for success in science are part of their understanding of science ability and appear to influence their teaching approach, how they advise students about their suitability for particular courses or careers and which students they treat as if they were able.

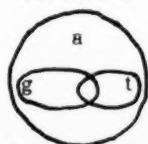
Most nations have an interest in identifying and nurturing ability in science. In the draft discussion paper from the National Technology Conference held in Canberra in September, 1983, it was argued that the nation's most valuable resource was its people and that our future economic and social development depends, in part, on our ability to ensure that young, able persons make their full contribution in the field of science and technology. At present, the early identification of able students is left to high school teachers, the exam systems and to others with an interest in the students concerned.

This pilot study was designed to identify the attributes which science teachers think are important in science students. The study involved a survey of science teachers using a questionnaire similar to that used by Trowbridge and Mintzes (1985). Some of the teacher surveyed were later interviewed to clarify and extend their responses.

THE SURVEY

The survey required about 20 minutes to complete. Teachers were asked to write down the given names of three students they were currently teaching, or have taught in the last two years, for whom they judge the description - "Has an excellent grasp of and aptitude for science" - best applied. The terms gifted and talented were not used in the survey. These terms are restrictive and refer to a much smaller proportion of the population than the term able. The relationship between the classes able (a), gifted (g) and talented(t) is shown in figure 1.

FIGURE 1



For each of these three students, teachers were asked to list four things (characteristics/aptitudes/traits/skills/qualities) which they considered in deciding who should be included in their short list.

They were then asked, "what three things (characteristics/aptitudes/traits/skills/qualities) did you consider most important when reaching a decision about who should be included in their list of three students?"

Subjects

The survey was distributed to eighty science teachers in thirteen government and three non-government schools within the Riverina Region. Schools were in towns of 2,000 - 50,000. This group included teachers with a variety of experience from first year out from training to subject masters of more than 10 years' standing.

Post-Survey Interview

Six of the teachers who completed the survey were then interviewed several weeks later. Each interview lasted approximately 40 minutes. The interviewer re-read their responses to the questionnaire and then asked each teacher to elaborate on their responses and the issues they raised.

SURVEY RESULTS

Thirty-seven (45% of the 80 teachers responded to the survey. All responses were read by each of the researchers. The team then came together to collate the responses. Where teachers appeared to refer to similar attributes, abilities or characteristics these were grouped together and tallied. It was convenient to establish four categories of

response viz: intellectual attributes; abilities; skills; and, personal and other characteristics. The teachers' perceptions of what is important in classifying science students as able or gifted are listed below.

TEACHERS PERCEPTIONS OF WHAT IS IMPORTANT IN
CLASSIFYING A STUDENT AS ABLE OR GIFTED IN SCIENCE

1	<u>Intellectual Attributes</u>	
	Inquiring-questioning attitude	30
	Conscientious, industrious, thorough, persistent, perseveres	28
	Communicates clearly	18
	Keen, interested and enthusiastic about science	15
	Seeks extra information/engages in wider reading in science	13
	Critical, analytical/logical	9
	Independent - needs little direction	8
	Determined to succeed/learn	6
	Imaginative and creative	6
	Open minded/suspends judgement	5
	Sets high personal standards/high achievement	5
	Considers all possible alternatives	3
	Honesty/intellectual humility	2
2.	<u>Abilities</u>	
	Finds patterns, links related ideas, discusses principles and possibilities	11
	Recognises and applies principles to solve problems	10
	Has high reading and maths skills	9
	Capable of abstract reasoning including thinking in terms of models	6
	Learns new science ideas quickly	6
	Has good memory of general knowledge/science achievement.	5
3.	<u>Skills</u>	
	17 of those surveyed indicated that students should exhibit a high level of performance in the following skills: observing, handling equipment, interpreting data and making inferences.	
4.	<u>Personal and Other Characteristics</u>	
	Well organised and neat	4
	Good listener	4

Perform well in tests	4
Good humoured	3
Attentive	3
Leadership skills and common sense	2
Positive attitude and pleasant outlook on life	2
Completes all work	2
Asks "friendly" questions	2
Good attitude to subject	2
Answers when asked questions	1
Completes all work on time	1
Gets work done in class	1
Participates	1

Sex of students nominated

One hundred and ten students were nominated as able by their teachers. The distribution by sex was male, 60%; female, 40%.

Interviews

Because the number of interviews conducted was small, no attempt has been made to generalise from them. However they were useful for interpreting the survey data, classifying the reasons for some responses and identifying implications.

DISCUSSION

There is virtually no literature on able students in science. Most writers have confined their attention to gifted and talented students.

A search of the literature reveals that there is a wealth of literature concerning gifted and talented children and the characteristics of these children (e.g. Blurton, 1983; Hargraves *et al.*, 1975; Creed 1982). One issue that has importance for this study relates to the distinction between giftedness and talent as these terms are not unanimously agreed upon. This problem is evident when authors discuss giftedness and talent in various subject areas. However, a reasonably widespread and recurring definition for this distinction suggests that a gifted student is one who has outstanding abilities or potential in a number of areas whereas the talented student has outstanding ability in one particular area (Creed, 1982). Renzulli (1977) has attempted to more clearly define what this outstanding ability should include by identifying three basic attributes of a gifted student:

- i) above average intelligence;
- ii) high level of motivation or commitment to the task; and
- iii) high level of creativity.

Similarly, there is a wealth of literature which describes and reports upon programmes designed for the gifted student (e.g. Schwarz, 1982; Endean and George, 1982; Creed 1982) either in separate learning environments or through enriching the normal classroom setting.

However, from an analysis of these areas of the literature about giftedness, very little direct attention and research has been given to either ways of identification of the able, talented or gifted student in science or to the attributes of students that are considered by science teachers as being important identifiers of these student. Part of this problem rests with the notion that science is a multi-disciplinary field which incorporates not only outstanding science ability but also both literacy and numeracy skills. Blurton (1983) has noted that the student must be good in both these skills to be successful in science. Further, science has a multifaceted nature which again makes it more difficult to identify the gifted science student. It is easier to identify the musically or artistically gifted student than to identify the gifted science student because the criteria valued as being important for giftedness in Physics or Astronomy may well be different to those criteria considered important in Geology or Biology.

On the issue of teacher identification of the gifted student, Callow (1980) has noted that "teachers develop a fairly rigid set of values by which they judge all the pupils they teach and these values are the result of training and experience." (p.112). Endean and George (1982), Tempest (1974) and Gallagher (1964) agree with Callow (1980) when he notes that the subjective assessment by teachers of gifted children is often inaccurate because of these rigid sets of values and that teacher identification is often based on student co-operativeness, and high interest or motivation in subject matter. In all of these studies, the identification issue was discussed at the broad level of general giftedness and not at the level of science teacher perceptions of and identification strategies for the able, talented or gifted science student. Consequently, the findings of this preliminary study have shown that:-

- (1) Almost all the teachers surveyed were able to identify three students they considered had an excellent grasp of and aptitude for science. This finding is similar to that reported by Endean and George (1982) who have found that teachers can identify students whom they consider are outstanding in science but the issue of whether or not these students were gifted students needs further exploration;
- (2) Teachers frequently had difficulty in separating the characteristics of good students and the characteristics of students with an excellent grasp of and aptitude for science. These teachers described students as neat, did well in tests, handed in work on time, attentive, good memory, conscientious etc. This difficulty is a common problem reported by Hargraves et al (1975) and Blurton (1983). Teachers of science

find it difficult to identify the outstanding science student because this ability can be expressed as a variety of abilities in different combinations for different sciences;

- (3) Teachers frequently described students in terms of desirable personality traits, e.g. sense of humour, gets on well with others, perseveres, self-motivated, wants to succeed, independent etc. This finding is quite similar to the research findings of Callow (1980) and Hargraves *et al* (1975) in which teachers tended to concentrate on personality attributes rather than on academic, intellectual or creative attributes as suggested by Renzulli (1977);
- (4) Some of the terms used to describe students were very general, such as has innate ability to learn, able to communicate clearly and effectively, has good mathematical skills. Some of these terms refer to the characteristics of gifted students in general. Blurton (1983) noted that this was a common phenomenon when teacher identification of the talented or gifted science student occurred. This is probably due to the multidisciplinary nature of science.
- (5) The majority of the teachers surveyed shared the view that science is particularly concerned with asking questions, inquiring, experimenting, and observing and communicating, but could not go much further in identifying more specific behaviour. This finding suggests that the majority of science teachers surveyed hold a view about the nature of science as being both process oriented and product oriented. This is encouraging and in part is consistent with the set of recommendations produced by the National Science Teachers' Association (Penick and Yager, 1983) for the identification and nurture of excellence in science. In particular, the teacher's role was described as providing encouragement for students to adopt inquiry modes of thinking that are drawn from active exploration of real world and relevant investigations.
- (6) It appears that science teachers are able to classify and make decisions about students in terms of some imprecisely defined concept of aptitude for or ability in science. This is consistent with Blurton's review (1983) of the literature in this area.
- (7) Teachers appeared to differ considerably in their implied views about:
 - (i) the nature of science
 - (ii) the purpose of science education and
 - (iii) the learning processes valued in the classroom.

These differences provided a basis for placing teachers into four groups.

The four groups are:

- (a) External: this group it would appear see their task as transmitting a fixed body of information efficiently and such issues as developing an understanding of the nature of science or considering how one learns, is outside their concern and do not warrant reflection. Such teachers value diligence, neatness and conformity.

- (b) Objective: this group appears to accept a Baconian view of the nature of science. Science is seen as describing an external reality. Such teachers value process skills, mathematical skills and achievement in exams.
- (c) Interactionist: this group appears to accept a more modern view of the nature of science and value such things as initiative, creativity and problem solving skills. There is a balance between procedural and declarative knowledge.
- (d) Other: some responses don't fit the above three categories since they relate to different issues and concerns.

The first three groups have something in common with the three types of science teachers - informers, enquirers and problem-solvers - identified by Eggleston, et al (1976).

We now envisage that the pilot study can be followed up by:

- i) comparing the constructs of beginning and experienced teachers,
- ii) developing a taxonomy of teachers based on the patterns and responses, and
- iii) relating the constructs of teachers to classroom practice and teaching/learning interactions.

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Research In Science Education, 1986, 16, 119-124.

INCREASING CURRICULUM RESPONSIBILITY: SCIENCE TEACHERS RESPOND TO A NEW CHALLENGE

Jeff Northfield

INTRODUCTION

A major review of science education is being undertaken in Victoria in a very different context from our last curriculum development efforts more than a decade ago. In the early 1970s the science education community co-operated in the nationwide project known as the Australian Science Education Project (ASEP, 1974). This project has been described as a typical example of the second generation curriculum projects produced in the late 1960s and early 1970s (Zoller & Watson, 1974). Curriculum development focused on the production of high quality materials by a central team making use of the current ideas. The science teacher was the target for dissemination strategies involving inservice education during the later stages of the project.

The current review of science education places the science teacher (not curriculum materials) as the primary focus for curriculum development. This changed emphasis can be understood only by considering some fundamental shifts in the context of schooling and recent interest in the implications of alternative frameworks research for school practice.

THE ESTABLISHMENT OF SCHOOL BASED CURRICULUM DEVELOPMENT AS EDUCATION POLICY

The rhetoric of school based curriculum development has existed in Victoria for about 20 years. The removal of external examinations up to year 12 meant that previous course prescriptions became advice for schools. There was encouragement for schools to develop their own curricula to suit local needs. ASEP by producing a large number of largely independent units and allowing students to choose from a variety of activities within units required science teachers to construct their own programs and this they did using the project units and other texts and resources (Owen, 1976).

This informal trend towards making the school the centre for curriculum development has been formalised in recent years by a set of Ministerial Papers (Minister of Education, 1985) which have placed curriculum responsibility at the school level. The

central authorities have therefore adopted two clear roles in the curriculum process - the preparation of broad guidelines and principles and the provision of resources and support to assist schools to translate policy into appropriate curriculum detail. It is the implications of these developments for external support of schools that is the subject of this paper.

The impact of alternative frameworks perspectives on school practice

The recent research interest in alternative frameworks and the broader perspective of constructivist approaches to learning are beginning to have an impact in teacher education programmes and classroom practice. As teachers become involved in implementing the ideas in the classroom it is clear that they need to develop a constructivist view of their teaching role (Gunstone & Northfield, 1986). It is very difficult to imagine curriculum materials or teacher's guides that can do very much more than provide awareness and guidance for the teacher. Eliciting and responding to student views is very dependent on particular classroom context and researchers have recognised the fact that it must be the teachers who research the range and relevance of teaching approaches in this area. The implications for practice are emerging from the work of teachers and the type of support they must be given is similar to that which needs to be provided to facilitate their increased responsibilities as curriculum developers.

Developing a Rationale for Supporting Schools

Teachers are being required to develop their own solutions rather than implement solutions developed outside the school. To the changing responsibilities outlined above could be added the changing teacher role in student assessment. School assessment associated with various moderation procedures are becoming an increasing responsibility for teachers. The remainder of this paper is concerned with the forms of external support that may be most appropriate as schools and teachers respond to changing demands.

TABLE 1

What should be supported?	
Developing enabling conditions in the school	Developing delivery systems to the school
Structural, organisational changes in the school	Changes in curriculum content to satisfy external requirements
School level development	Exemplary materials and practices
Problem solving strategies	Product focus
<u>Organising the support</u>	
Discretionary funds for the school	Funds for defined purposes
Continuing support	Initial (short term) support
School initiative	External initiative
Adaptation of ideas	Implementation with fidelity
High local involvement in change efforts	Low local involvement in change efforts

Louis et al. (1985) developed contrasting pairs of descriptors to highlight a range of differences in the way school support can be provided. Table 1 takes some of these descriptors (together with others) to summarize important issues in considering how schools might be supported. As an introductory statement, support for schools within an overall policy of school based curriculum development would be characterised by the descriptive statements on the left hand side. The statements on the right hand side represent more traditional views of the purpose and role of external support for schools when there has been external development of curriculum details which need to be communicated to schools. In the next sections of this paper a selected number of initiatives will be outlined which indicate some shift in emphasis towards the left hand set of descriptors in Table 1.

Consultancy Support for Schools

Consultancy is one of the most obvious ways of providing external support for schools. In recent years there has been a tendency to see schools as being best served by general or process consultancy rather than the more usual subject consultancy. The increased responsibilities of schools and the nature of the descriptors on the left hand side of Table 1 seem to provide support for such a trend in consultancy. However one study of schools suggests that future planning of consultancy services will require very careful consideration.

One region in Victoria has the opportunity to review consultancy services for 1987 because all existing staff complete their present terms as consultants. The school responses in the debate about the future shape of consultancy services has proved very interesting. While acknowledging that their major needs for external support are in areas of school-wide curriculum decision making the schools expressed a strong preference for subject consultancy rather than general forms of consultancy. Schools are therefore looking for assistance in general and process areas but would prefer consultants with established subject expertise.

This apparent anomaly can be understood if we consider the factors associated with a school having confidence in a visiting consultant. A major factor in school acceptance of a visitor is demonstrated subject expertise. Such a person has credibility, and interactions within the school are more likely to be fruitful.

Teachers also have different types of concerns. In reviewing three years of consultancy two science consultants made the following responses to the question 'Could a general curriculum project team carry out a similar role to a science project team?'

One thing that gave us (a science project team) credibility was that we were science teachers and the teachers' first concern is their immediate area of teaching, their secondary concern is the general curriculum of the school ...

One observation would be that teachers are not surviving very well in their subject area and until they survive well in their subject area there is great

reluctance to worry about the impact of the general curriculum. Science teachers should be supported first as science teachers - get them doing that job very well - then look at the general curriculum issues.

(Northfield, Brandon & Wallis, 1985, p.7)

At this stage the most appropriate consultancy policy would be to continue to appoint people with demonstrated subject expertise to most positions. The challenge will then be to provide inservice programmes which allow the consultants to offer support in more general areas of school activities.

THE FUTURE OF SCIENCE EDUCATION: SUPPORT FOR TEACHERS AND SCHOOLS IN A CHANGING CONTEXT

The Ministerial Papers (Minister of Education 1985), especially Ministerial Paper 6, raised many questions in the minds of teachers and schools. What does it all mean for schools? How should schools respond to greater curriculum autonomy and responsibility? In response to questions such as these the central authorities set up the Curriculum Frameworks Project with the intention to:

- help school councils to determine policies;
- enhance school-community participation and consultation;
- help schools to plan curricula systematically;
- develop a P-12 perspective on teaching and learning.

(Education Department of Victoria 1985, p.3)

A science team is one of ten centres contributing to this project and at this stage they have produced a three page introductory statement outlining contemporary issues and the perspectives which will be followed in areas of curriculum content, curriculum organization, teaching and learning approaches, assessment, and course evaluation (Education Department of Victoria 1985, pp.42,43). Great care has been taken to ensure that the initial ideas in these areas are in accord with current views in the science education community.

The introductory statement also gives some indication of what teachers can expect during 1986 to facilitate their task of producing a science program for their school.

A variety of documents and materials will be produced through the Frameworks project; support personnel will be available; and school networks will be encouraged.

The Science Framework P-12 will be presented in three parts. The first part will outline the rationale and philosophical position. The second part will build on the first, detailing guiding principles and criteria for course design and teaching practice. The third part will include recommendations for teaching, learning, assessment and course development, covering the areas described above. These will be supported by a collection of episodes, activities and vignettes which illustrate Parts 1 and 2.

To support the central document, a range of materials will be developed, including sample course outlines; collections of illustrative units, worksheets and

activities' teaching, learning and assessment strategies; a computerised data base of Frameworks resource materials; materials to aid program evaluation; strategies for modifying existing programs; operational policies such as equipment and facilities, organisation and management, safety, use of animals and the conduct of fieldwork.
(Education Department of Victoria 1985, p.43)

This thrust toward providing support and resources for teachers to develop curricula has been strongly supported by the state science teachers' association. Recent conferences and policy statements (Science Teachers Association of Victoria, 1985) have placed the science teacher as the key participant in the curriculum development process. A significant proposal is to facilitate the formation of clusters of teachers from nearby schools to share ideas and work co-operatively on curriculum issues. At least three cluster groups of teachers have been operating for two years. Accounts of these efforts have encouraged the Frameworks team and the science teachers' organization to promote the approach as a model for supporting school based curriculum development. The proposal includes the linking of cluster groups through a central co-ordinating group to form regional and statewide networks for exchange of ideas.

The intentions and the practice - achieving appropriate forms of teacher support

The Frameworks project and the proposed cluster arrangements have been developed to support science teachers with a major responsibility for curriculum development. Such support should foster the types of features set out on the left hand side of Table 1 (viz. school level development, problem solving strategies, continuing support, adaptation of ideas). The establishment of networks is therefore intended to provide opportunities for science teachers to reflect on their existing teaching practice and clarify ideas and values they would wish to develop in their science classrooms. The clusters can then be a forum for discussion of issues and developing responses to problems. The cluster groups which have been operating have developed curriculum materials for 'problems' such as assessment of practical skills in science and establishing urban trails to highlight science concepts.

Of particular interest is a group of teachers who meet regularly to share ideas and experiences related to the implementation of alternative frameworks perspectives. Curriculum implications will emerge from their efforts, and generalisations about the process of teacher involvement are likely to be more significant than details of particular teaching techniques and resources. Opportunities for the teacher to be a 'reflective practitioner' (Schon, 1983) are therefore underlying the arguments for forming such teacher clusters.

Most inservice approaches rely on external inputs which influence classroom practice with some fidelity. Teachers are expected to alter practices with the aid of appropriate resources. With clusters there is the assumption that change begins with the science teacher's knowledge and values. Curriculum changes occur when teachers develop their

own understanding of the issues and this requires time and the support, ideas and reactions of colleagues. This version of how clusters can work is in accordance with widely accepted principles for fostering educational change (e.g. change is a long-term process, change in individuals precedes fundamental changes in their practice).

These policies for supporting science teachers are being considered and implemented at a time of resource constraints for education. It is becoming difficult to argue for time allowances for teachers to participate in clusters, and staff to co-ordinate to provide resources for a largely untested model of teacher support remains the greatest challenge.

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Research In Science Education, 1986, 16, 125-134.

NEW DIRECTIONS FOR AUSTRALIAN RESEARCH ON SCIENCE TEACHER EDUCATION

Richard Tisher

INTRODUCTION

The science education of primary and secondary teachers is a major enterprise in this country yet it appears to receive only a small amount of attention from researchers. During the past decade, for example, publications such as Research in Science Education and The Australian Science Teachers' Journal contain only about 21 reports of research on issues associated with science teacher education. The term research is taken to mean investigations about the issues. Surveys, experimental designs, case studies and action research projects are considered to be included by the term, whereas philosophical treatises or position papers about the nature of science teacher education are excluded. The term science teacher education is taken to include pre-service education, the induction of beginning teachers and professional development programmes (e.g., in-service programmes) for experienced teachers. If these meanings about research and science teacher education are accepted, what questions would we expect research on science teacher education to address? Undoubtedly some educationists would argue that the nature and the impact of different programmes on teaching skills should be evaluated. Others, who are concerned with long-term professional development, might argue that information should be gathered about the effectiveness of programmes in fostering teachers' attitudes towards, and skills in reflecting critically on their own teaching. On the other hand, those who accept McIntyre's (1980) point of view about the role that ideologies and cognitive schema (for example, how persons construe teaching when they are thinking about it for themselves) play in teacher education will want to document the changes in teachers' cognitive schema during and following a teacher education programme. These are but a few of the host of issues for research and during the last decade in Australia science educators have directed their attention primarily to the characteristics possessed by teachers in pre-service programmes, and to a lesser extent to the development of teaching skills in pre-service or in-service programmes.

The 21 investigatory projects which have been located consist mainly of cross-sectional surveys using questionnaire or interview techniques to collect data. Five surveys were longitudinal in nature, involving data collection at the beginning and end of a short time period, for example, a unit of work within a course, a practice teaching period (3 weeks), a semester (about 13 weeks) and an academic year (about 9 months). Three of the 21 studies can be categorised as experimental since they contained a "treatment" condition and pre- and post-testing. Two studies may be described as action research projects even though the investigators did not appear to comply with all the conditions that may be expected for an action research study, and one, or two, may be classed as case studies presented by individuals who played major roles in the programmes under scrutiny.

BOX 1

FINDINGS ABOUT THE CHARACTERISTICS
OF PRE SERVICE TEACHERS : I

1. The four most preferred strategies for teaching primary science by entrants to a teacher education programme are (a) providing practice in process skills, (b) providing first hand experiences, (c) allowing individuals to experiment and (d) giving explanations.
2. A greater understanding of and a liking for science are fostered in primary trainees when an Open University type science course with home experiments, projects and tutorials is incorporated into their teacher education programme.
3. Highly ranked self-perceived needs of Dip.Ed. students before and after a practice teaching period are the abilities to cope in the classroom, gain practical teaching skills, develop relevant understandings and explore one's own capabilities.
4. Primary trainees' attitudes towards hands on experiences for pupils declines during a practice teaching period. Males become more positive in their feelings about their own teaching of science whereas females become more negative.
5. A large number of pre-service primary teachers do not use formal reasoning patterns and do not possess the patterns which activity-centred science curricula seek to develop.
6. Primary trainees who score low on reasoning ability tend to be those who have studied Biological Sciences at Year 12.

The experimental subjects in all studies consisted of individuals who were enrolled in formal courses or who had volunteered for an in-service programme. Four of the investigatory studies involved Diploma in Education students in "end-on", one-year programmes, one study involved experienced teachers in a self-instructional in-service programme on Harvard Project Physics, another surveyed beginning teachers, and the others used trainee teachers in concurrent programmes, usually in a College of Advanced Education.

In passing, it is appropriate to note that there are a number of reports in the Australian literature about innovative science teacher education programmes. For

example, in a special issue of The Australian Science Teachers' Journal in 1972, Hawkins and Symington (1972) described what one College was doing with respect to science courses for primary school teachers, Northfield (1972) described a concurrent B.Sc.(Ed.) programme and Fensham & Fyfield (1972) and Tisher (1972) described innovative approaches to science teacher education within Diploma in Education programmes in two universities. Recently Gunstone and Northfield (Note 1) have referred to some of the practices they follow in training science teachers, but their paper, as well as reports such as the preceding ones in The Australian Science Teachers' Journal, have not been classified as research on science teacher education since they are not clearly investigatory in nature. The perspectives from which the authors write, however, have been shaped by their experiences with pupils, research on teaching and pupils' understandings, and teacher trainees.

CHARACTERISTICS OF PRE-SERVICE TEACHERS

About 50 percent of the reports on trainees' characteristics deal with preferences, attitudes, feelings of confidence and reasoning abilities. Appleton (1983, 1984), for example, in a one-year longitudinal study, surveyed first-year primary trainees at the beginning and end of year to discover what preferences they held for various strategies for teaching primary science. In another longitudinal study Dooley and Lucas (1981) surveyed the changes which occurred in first and second year trainees' attitudes to science and science teaching when they were respectively exposed to a content based science course and a unit dealing with curriculum. Information related to trainees' feelings of confidence about their teaching has been gained in an experimental study involving primary trainees (Symington, 1982), and in a longitudinal project involving Diploma in Education students (Beasley, 1981), while information about pre-service primary teachers' formal reasoning abilities has been obtained from a cross sectional survey of 299 second year trainees (Garnett & Tobin, 1984; Tobin & Garnett, 1984). Other investigations have focussed on the self-perceived needs of Diploma in Education students before and after practice teaching (Gunstone & Mackay, 1975), changes in attitudes to teaching science during practice teaching (Appleton, 1981), primary trainees' beliefs about science teaching (Dawes, 1982) and their understanding of and liking for science (Walsh et al., 1980; Walsh & Lynch, 1985) and Diploma in Education students' perceptions about pupils, teaching experiences and collaboration with others (Fawns, 1984). The salient findings from these studies are summarized in Boxes 1 and 2 using phrases comparable to those used by the authors of the research reports.

BOX 2

FINDINGS ABOUT THE CHARACTERISTICS
OF PRE-SERVICE TEACHERS : II

1. The four most preferred strategies for teaching primary science by trainees at the end of their first year are, (a) allowing individuals to experiment, (b) providing first hand experiences, (c) allowing pupils to devise own experiments and (d) providing practice in process skills.
2. Whereas a majority of Dip.Eds. gain confidence with respect to teaching, and especially with respect to their abilities in test construction, about one in every two feel confident about organising and supervising field trips and preparing inquiry oriented instructional sequences.
3. More than two thirds of primary trainees, at the end of their third year, believe teachers should admit when they are wrong, a good science background is not essential in order to teach science, and the same work should not be done by all pupils.
4. About half of primary trainees at the end of the third year believe a syllabus is necessary in primary science.
5. Primary trainees develop more favourable attitudes towards science teaching during the second year and their pre-service education.
6. A deliberate six-week programme aimed to help trainees reflect on their own teaching and be self-critical and which uses diary records, videotapes and discussions, is successful in developing trainees' perspectives about pupils, fluctuating experiences in teaching and difficulties associated with collegial collaboration.

It is appropriate to note that the projects reported by Walsh et al (1984), Walsh & Lynch (1985) and Fawns (1984) have a number of the characteristics of action research. Walsh et al (1984) and Walsh & Lynch (1985) discuss the development and impact of a science course for primary trainees. The course, which was incorporated into a teacher education programme, was an adaptation of an Open University one characterised by home experiments, projects and tutorials. An evaluation of the innovation (Walsh & Lynch, 1985) indicted that the trainees understandings in and liking for science were enhanced. The project discussed by Fawns (1984) was not designed to enhance understandings in science. Its specific objectives were to help Dip.Eds. reflect on their own teaching and be self-critical. Diary records, videotapes of students and discussions were used to achieve the objectives and it was noted that some of the pay-offs were that there were changes in trainees' perceptions about pupils, teaching experiences and the difficulties associated with collegial collaboration. It seems that the nature of the Fawns & Walsh et al projects would have forced the researchers to take some account of the complex nature of teacher education - a complexity which lies in the various people involved in teacher education, the range of social, political and educational ideas associated with it and the processes it uses to develop thinking, competent teachers who are knowledgeable about the content and process of education, pupils and the context of schooling. Most of the other projects referred to above were not designed to consider or respond to a large number of variables.

A number of implications can be drawn from the findings listed in Boxes 1 and 2 but only a few comments will be made here. The finding that a large number of primary trainees do not possess reasoning patterns which activity-centred science curricula seek to develop suggests many will encounter significant difficulties in implementing an effective primary science programme (Tobin & Garnett, 1984). Furthermore, when these findings about reasoning abilities are coupled with those about changes in attitude to hands on experiences for pupils, abilities to cope in the classroom and with the generally accepted view that pre-service teachers hold a number of inaccurate and false science concepts - a view that appears plausible according to research on trainees' science concepts in New Zealand (Happs, 1984; Hope & Townsend, 1983) and Australia (Note 2) - it is clear that more needs to be learnt about the ways to arrest certain attitudinal changes, correct erroneous science concepts and develop teaching skills.

BOX 3

SKILLS COMPONENTS IN TEACHER EDUCATION

1. Strategy analysis procedures consisting of model presentation, peer teaching, analysis and assessment of correspondence to the model, and feedback on performance, are effective in improving the quality of trainees' teaching skills for activity-oriented science.
2. Strategy analysis procedures are more effective than merely mastering a teaching model for changing teacher behaviour and for developing process skills.
3. Student teachers ask more questions of their pupils in demonstration-discussion phases of an ASEP unit than during group activity phases. About 22 percent of the demands on pupils are higher-cognitive and 50 percent management ones.
4. A two-way self-instructional in-service programme containing micro-teaching, review, video-feedback and re-teach cycles is effective in enhancing teachers' skills at probing.
5. Primary trainees' choice of materials for science lessons is affected by a variety of factors: there is no simple linear relation between that and their background in science.
6. When primary trainees' knowledge of science is extended they become more confident in teaching science, and they extend pupils' ideas during verbal interaction.
7. Only two out of five pre-service primary teachers alter their initial broad perceptions of inquiry teaching with more specific detail after instruction in curriculum and practice teaching. By and large trainees lack clear perceptions to adequately implement inquiry teaching.

SKILLS COMPONENTS IN TEACHER EDUCATION

By and large pre-service teachers value programme components that develop their teaching prowess. When they reflect on their teacher training they invariably state that more time should be given to courses on teaching methods and teaching techniques. Certainly this was the view expressed by 34, three-year-trained diplomates during their

first year of science teaching (Dawes & Ticehurst, 1978) and it accords with the view held by a majority of Australia's beginning teachers (Tisher, Fyfield & Taylor 1979). But even though trainees, beginning teachers and teacher educators believe the development of teaching skills is an important component of teacher education, science education researchers have not devoted much time and effort to study the matter. During the last decade there are only seven reports of Australian studies dealing with the development of science teaching skills. One (Rentoul, 1971) involved 45 teachers in a two-day in-service education programme on Harvard Project Physics. The programme was self-instructional involving micro-teaching, review, video-feedback and re-teaching sessions aimed at developing teachers' probing and questioning skills. Two other reports on strategy analysis (Tobin, 1985; Tobin, Pike & Lacey, 1984) describe experimental studies involving 112 college students enrolled in science education courses. In these projects the pre-service teachers learnt about models appropriate for activity-oriented science courses and engaged in peer-teaching (i.e., behaviour modelling) which was followed by (a) an analysis of their teaching to note whether it corresponded to the proposed models and (b) feedback about the teaching. Another investigatory project examined the questioning strategies used by six Diploma in Education students when using the ASEP unit on "Forces" (Fawns, 1977). The Smith and Meux classificatory system was employed to categorize the intellectual demands made and the findings were compared with those obtained in an earlier study involving Queensland teachers following a conventional combined science programme (Tisher, 1970). It was noted that the proportion of lower cognitive questions (26%) in the trainees' lessons was much less than what had occurred in the experienced teachers' lessons (75%). Three studies involving primary trainees focussed on the pre-service teachers' choice of alternative verbal behaviours (Symington, 1980) and materials to be used in science lessons (Symington, 1982), and their perception of inquiry teaching plus the extent to which they implemented lessons with inquiry characteristics (Skamp & Power, 1981). The findings from these three and the other 'skills' investigations are summarized in Box 3 using phrases derived from the respective research reports.

As Box 3 indicates there are not a large number of findings related to the development of science teaching skills and all the projects were of a short duration. There are no studies tracing skills development during one or more years and none investigating the extent to which acquired skills and confidences are maintained during the first few years of teaching. It would be interesting to know to what extent the various training components (e.g., strategy analysis, micro-teaching), used in the investigations were subsequently retained in the respective pre-service programmes and whether they still exist in those programmes.

NEW DIRECTIONS

The preceding discussions reveals, albeit briefly, the state of Australian research on science teacher education. There was not an extensive amount of research during the last decade and the resultant knowledge base is a small one to inform practice. It must be coupled with the findings derived from the more general research on teacher education in Australia. There has been a respectable amount of diverse research during the past ten years dealing with such matters as perceptions of teaching as a career, characteristics of teacher trainees, the nature and impact of pre-service programmes, skill components in pre-service education, the nature of school experience (the practicum), training supervisory teachers, beginning teachers' concerns and attitudes, and needs and provisions for in-service education (Note 3). That research has yielded an array of diverse findings but it is intriguing to reflect upon what has been avoided by the research workers. For instance, detailed evaluations of teacher education programmes are rare. In other words, teacher educators are failing to check and report upon the nature and effects of their programmes. One new direction consequently, for some future research on science teacher education, is to engage in evaluations of long-standing as well as new science teacher education programmes.

Another omission from the research on teacher education is the due regard for the complex nature of the teacher education enterprise. As was noted earlier that complexity lies in the variety of people involved in teacher education, the range of social, political and educational ideas associated with it and the processes used to develop competent and knowledgeable teachers. Each of the investigations to date have considered only a few of the variables associated with the complex enterprise. Now action research projects are capable of taking greater account of complexities and more pay-offs may result if more of these were conducted on science teacher education. If that is done Elliot's (1980) advice should be heeded. He maintains that there is a need for action research projects to incorporate a highly developed critical perspective and not to stop short at class-room, lecture-room, university-bound or school-bound interpretive or phenomenological descriptions.

Elsewhere (Note 3) it has been stated that it is rare ...

"for teacher educators to be the main focus of a study and that situation must be rectified in the future. McIntyre (1980) suggests that research on teacher educators could contribute to quality in teacher education by making them more aware of their concerns, assumptions and ideologies and of how these relate to their positions within distinctive types of organizations. He stresses the important role that ideologies and cognitive schema, for example how persons construe teaching when they are thinking about it for themselves, play in all facets of teacher education, and how these can filter the effect of components of a programme. If his point of view is accepted then future

studies must take greater account of the ideologies and cognitive schema of persons involved in teacher education programmes. It is salutary to note how rarely this has been done, particularly in projects designed to enhance individuals' teaching or supervisory skills. As McIntyre (1980) implies the value of these skills projects may lie very much more in terms of their gradual development of participants' cognitive schema for teaching or for supervision, than in terms of participants' acquisition of specific behaviour patterns. Future research could, with some profit, assess the value of skills projects in the way suggested" (Note 3).

There are numerous other proposals that could be presented as new directions for research, for example, studies about the effects of interactions between the ideologies and cognitive schema of trainees, teacher educators and supervising teachers, the effects of timing and sequencing the components of programmes, the effects of different modes of practice teaching, ways of developing supervisory skills of co-operating teachers and lecturers (Note 4), and effective ways to educate trainees so that when they are teaching they will be reflective researchers in their own classrooms. Space limitations preclude further development of these and other ideas. The reader is left to reflect on the suggestions and to extend the list of new directions. Clearly what is proposed constitutes a challenge to science educators to devote more time and effort to research on science teacher education thereby extending the knowledge base which will inform practice.

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EXPLANATION AND EXPLAINING IN SCIENCE EDUCATION

Paul Strube

It is not customary to begin papers dealing with educational matters with quotations that do not come from educationalists of merit, but whether or not Samuel Johnston contributed to the field of pedagogy, he serves admirably to introduce this topic. After prolonged discussion and debate on a complex political issue with an apparently unworthy opponent, Boswell reports him as saying: "Sir, I have found you an argument. I am not obliged to find you an understanding."

It is this dichotomy between argument and understanding that is the theme of this paper. For teachers are obliged to not only find arguments but create understandings as well. It is the argument of this paper that this dichotomy has been misunderstood by teachers, and it is the intent of this paper to share some sort of understanding of the associated problems. This is not intended as mere word-play here, but to express the crucial features of the dichotomy.

It is necessary to begin by acknowledging a debt to the very fine work done on this dichotomy by Jane Rowland-Martin, in her work Explanation, Explaining and Teaching (Rowland-Martin, 1970). She very ably points out the nature of the distinction in analytical terms, and my purpose is to extend her thinking more specifically to some current problems in the teaching of science. The words 'argument' and 'understanding' need clarification. Dr. Johnston uses 'argument' as a noun of course, and its closest equivalent is probably explanation. As a first approximation, an explanation here is taken to be an argument crafted to represent the current best view of the question under consideration. For example, if someone makes the request - "Why does an iron rod expand upon heating?" - the explanation will consist of statements from physics representing the best current views from physical theory. These statements will ideally be connected in such a way that, taken together and considered as an argument, they do in fact offer an explanation of the phenomenon under consideration. Therefore an explanation is seen to be a structure, if you like, and the statements and their connections can be written and displayed independently of any person providing the explanation. It is also discipline-

bound, in the sense that different areas of knowledge and craft will have different ideas as to what are acceptable explanatory structures. This simply means that what will be allowable as an explanation in one field, say religion, will not necessarily be acceptable in another, say science. The best current example of this is the debate between Creationism and Evolutionary Theory as rival explanations for the same phenomena - the current diversity and inter-relatedness of life. Put crudely, miracles are not allowable as part of the explanatory structure of modern science, and natural law is not sufficient within modern religion.

Notice that this use of explanation removes the power of any particular advocate to provide an explanation by force of persuasion. An explanation is not an argument in the sense of rhetorical disputation. The advocate can, however, attempt to convince others to reject the explanations offered by the field of study.

The other term of interest is that of understanding, but there are no intentions of dealing in any strictly analytical way with that concept here. Dr. Johnston's phrase is best seen as equivalent to - I'm not going to attempt to explain it to you. Now the key word becomes explaining, and it forms the dichotomy with explanation. Unlike an explanation, explaining is an act - it is the act of getting someone else to understand something. This activity is not necessarily discipline-bound, but is primarily an educational activity. It is common to the everyday act of giving directions to someone who is lost, or lecturing in a University, or explicating a poem to a group of students. This act can make use of a wide range of devices - drawing analogies, building models, reasoning from prior experience, defining, pointing out and pointing to, demonstrating, giving examples, drawing maps and diagrams, using metaphors, and so on.

This dichotomy can now be expressed as between presenting an explanatory structure, and performing an activity that explains that structure to someone.

An explanation is not a doing at all...Although the things one does with or to explanations may themselves be doing, the explanations one does things with or to are not doings, (but) sentences or statements of some sort or another. (Martin, 1970).

Why spend so much time developing such a dichotomy? There are several important reasons for doing so, important enough to be outlined with some care.

Firstly, there is still uncertainty evident among some educationalists and philosophers of education between explaining and explanation, which can be illustrated with a line from Polanyi and Prosch's book Meaning (1975).

To define the explanation of an event as its subsumption under a general law leaves unexplained its capacity to relieve puzzlement and isolates it from numerous other, more fundamental acts which have this capacity. Explanation must thus be understood as a particular form of insight - an insight that relieves our puzzlement through the establishment of a more meaningful integration of parts of our experience, achieved through the subsumption of a natural law under a more general law (Polanyi and Prosch, 1975).

Here the act of explaining - of relieving puzzlement - is clearly confused with the explanation.

Secondly, if such a dichotomy is taken as meaningful, and if science teachers are indeed responsible for elaborating both sides of the dichotomy to students, then it becomes an important task to identify the explanatory structures within the various sciences. Polanyi and Prosch refer to explanation as a "particular form of insight", which is not the usual meaning of the term. Philosophers of physical science have been actively exploring the nature of explanation in physics for a long time, and a coherent, if actively debated, structure of explanation based on natural law has been developed. A traditional account of this structure is given in the following outline form based on the work done in the 1960's by Carl Hempel.

- (a) The presence of a law or generalization about the phenomena under consideration.
- (b) Empirical statements about observable conditions with regard to the phenomena.
- (c) Internal consistency in the chain of reasoning between premises and the logical conclusions.
- (d) Empirical truth in the sense that the conditions do, in fact, prevail and that the generalization is, to the best of our knowledge, well founded. (Hempel, 1965).

Every step of this account, which may be labelled an inductivist view of explanation in science, has come under criticism from philosophers of science. The whole question of what counts as an explanatory structure even in physics has become confused. Our first definition of an explanation as the current best view needs considerable refinement.

Traditionally, four types of explanatory structures have been presented. Aristotle's Four Causes, Cause and Effect relationships, Empirical accounts, and Inductivist/Deductivist accounts (Strube, 1985). It is therefore important that such a question become a centre of discussion by teachers and researchers because of the uncertainty surrounding the relations between science and other human activities concerned with understanding, such as religion. Teachers need to explore with students the ways of acting on the world that are distinctively scientific, and explanatory structures are one of those distinctive features.

Far more immediately, there is strong evidence that explanations, for many common phenomena, are not in fact offered in science education at all. Consider the case of the iron bar again. An examination of 54 physics texts for senior pupils written between 1880 and 1982, all of which mentioned thermal expansion, reveals not one offered explanation. Statements are limited to some version of "expansion is caused by heat". Explanations, based on any given structure, are not the purpose, it seems, of science textbooks. There is a tradition in physical science texts, which can be traced back at least as far as T.H. Huxley, that scientific explanation consists solely in giving the cause of the phenomena.

Thus we believe that everything is the effect of something which preceded it as its cause, and that this cause is the effect of something else, and so on, through a chain of causes and effects which goes back as far as we choose to follow it. Anything is said to be explained as soon as we have discovered its cause, or the reason why it exists; the explanation is fuller, if we can find out the cause of that cause, and the further we can trace the chain of causes and effects, the more satisfactory is the explanation (Huxley, 1880).

An examination of science texts reveal that the authors assume just such a view of explanation, and are content to state, for example, that movement is caused by force. The difficulty with leaving the explanations at such a point is that it fails to differentiate between it and such statements as "misfortune is caused by Neptune ascendent in your sun sign", or "poverty is caused by alienation".

Turning to the other side of the dichotomy, explaining, consider the following example. Suppose the current best view of the expansion of a metal rod upon heating looked like the following:

Statements about the iron bar; e.g. its electronic structure, how it bonds to neighbouring iron atoms in the solid state, crystalline structure and initial conditions. Statements about the nature of heat; e.g. from thermodynamics and quantum levels. Law statements relevant to the phenomena; e.g. the laws of thermodynamics.

Specific connections between the increase in heat and increase in both kinetic and potential energy, and increase in length of the bar.

Picture all the above written out in full detail, and presented to a learner. There is of course likely to be a great deal of puzzlement remaining. The act of explaining is to bring about an understanding suitable to the capacities of the learner and the purposes of instruction. But that understanding has two components. One is an understanding of the explanation itself, of course. The learner must come to understand that what has been presented is what counts as an explanation in the discipline; that this is the model of explanation to be used. But as important, if not more so, there must be an understanding of each of the components of the explanation. In other words, the learner should come to understand the basis on which statements about the iron bar are made, for example.

This implies somewhat more than what some science educators have been arguing for since the beginning of science education in the 19th century - instruction in the methods and ways of approaching experience that are felt to be uniquely scientific. As can be seen in their textbooks, where explanatory structures are available for study, the emphasis of those science educators was too often on the unquestioned acceptance of established laboratory techniques and inductive arguments from given axioms and laws, rather than on any critical appraisal of their faith in those methods (Strube, 1985).

It may also be the case that explaining is not completely independent of the discipline under study. If science is thought of, in part at least, as a method of enquiry, then it may be best to use that method in teaching science. But this is not a strictly logical conclusion - learning psychology may have as much to say here as common sense.

If students are to learn the reasons why science has the explanatory structures it does, is it in fact necessary that they do some work in the laboratory and investigate a few phenomena for themselves?

What is also becoming increasingly clear is that the sciences are not equal in their reliance on experiment, empiricism, deduction, or whatever are taken to be the defining criteria of science. Chemistry is far more experimental than cosmology; biology far less abstract than physics. These differences present real problems to the elaboration of science to learners in schools, particularly in general science classes. It therefore emphasises the important need to explore the defining characteristics of each science, and hopefully match the act of explaining not only to the learner but to the task.

The traditional act of explaining in physical science textbooks has been the following.

The usual instructional pattern is to offer a definition, give examples of the principle either in the laboratory or from real life situations, and then argue logically for the generality of the definition.

Instruction is generally limited to statements of what is the case; i.e. simple telling.

The role of the laboratory is commonly reduced to verifying results.

Authors are not concerned to reduce scientific concepts to the already familiar; i.e. they are indifferent to the world of the reader.

By not distinguishing between explanation and explaining, a great deal of confusion can arise in the minds of teachers and textbook authors when they try to collapse them together. This may partially explain the misrepresentations and misapplications of physical principles discussed by Warren (1965) in his The Teaching of Physics. Teachers, and teacher/authors, may be more than willing to sacrifice the explanation in the act of explaining.

Beyond this, there is the difficulty faced by teachers of science as they respond to uncertainties about the view of science to be taught at schools. Since the beginnings of formalised school science in the mid 19th century, there has been a debate between proponents of a view of science as a method of acquiring knowledge, and those who see science as the body of knowledge accumulated by that method. Which view has prevailed at any given time has, in great part, been due to decisions based on the purposes of science education, rather than on any examination of science itself. These purposes are often political, social and educational in ways that have nothing to do with science as a discipline. A current form of this debate is asking whether science education should play a role in helping the learner to personally respond to science-related questions confronting society, such as pollution and bioengineering, or whether it should limit itself to providing explanations for such phenomena. The dichotomy between explanation and explaining enters this debate in a crucial way. Explanations in science are discipline-bound, and will

only be appropriate and workable within the framework of scientific activity. For those explanations to be meaningful, a certain amount of scientific knowledge is essential. Responding to science related questions need not demand the same level or type of knowledge. The difference in content and methodology between these two views can be best seen in an example. A course of study designed to offer explanations for the phenomena associated with acid rain and its effects on the environment will be considerably different from one which uses rather than establishes scientific information to form personal responses to the effects of acid rain.

If accepted, arguments outlined here would suggest that teachers, textbook writers, researchers and curriculum designers need to carefully examine the nature of the dichotomy between explanation and explaining. Some consideration must be given to the question of what is an explanation in science - is it empirical, causal, axiomatic? And the act of explaining must take into account levels of explanation, the match between explanation and teaching, and conveying to the learner the distinctive model of explanation within the science being taught.

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Research In Science Education, 1986, 16, 141-149.

TEACHING, LEARNING AND THE CURRICULUM 1: THE INFLUENCE OF CONTENT IN SCIENCE

Ian Mitchell and John Baird

BACKGROUND

This paper, and the one following, report on two different aspects of the Project for Enhancing Effective Learning (PEEL) at Laverton High School. PEEL aims to improve the quality of classroom learning by training students to be metacognitive learners. This means they will take greater responsibility for, and control of, their learning. Their learning will be informed, active and purposeful, involving positive learning habits which will have been taught by the PEEL teachers.

The project, which extends earlier research by Baird (Baird, 1986), was set up by the authors at the end of 1984 at Laverton High School where Mitchell teaches part-time.

In 1985 it involved ten teachers of five classes, teaching six different subjects at three year levels. In 1986 there are thirteen teachers teaching eight different subjects to eight classes at five year levels. The project is proceeding by participant action-research: teachers determine and control the procedures attempted, and evaluate teaching and learning behaviours as well as outcomes; students evaluate procedures and monitor changes in learning behaviours and outcomes.

Metacognition involves a wide range of learning behaviours. One set of these comprises those associated with the interaction between students' prior views (Children's Science) and the Scientists' Science they hear in the classroom. It was anticipated that change in cognitive structure from the first to the second would be facilitated by training for general metacognitive behaviour. In this paper, we report a major finding common to general metacognitive training in science and, more particularly, to restructuring of Children's Science. This finding is the importance of content in determining the nature and success of change in learning behaviours and outcomes. As will be described, the different conceptual and metacognitive demands of both different content and their

intended activities militate against the use of a general, content-independent strategy for fostering either of these goals. The implications of these different content-related demands for the sequencing of curriculum content will then be discussed.

TRAINING FOR METACOGNITION

Results

The technique the group began with was intended to be relatively content independent: at the end of each lesson, the students were asked to record in a 'PEEL diary' what they thought the main topic of the lesson had been, what they thought the main task had been, why they thought they had done this task, and one thing which puzzled them. There was more than one reason why this technique failed at that time, (Mitchell & Baird, 1985), however one was that it was too general and hence too abstract for students who had had no experience of active learning. They could not see its purpose nor see any benefit for them in using it. After some weeks, the teachers shifted to techniques involving questions which were more set within the content. At the time, one Year 10 class was studying Light and Colour. This unit involves a number of competing models variously proposed by the students, artists, printers and physicists. This content permitted the teacher to focus on a number of the strategies involved in generating adequate metacognition. These strategies included focussing on the need to retrieve prior views; searching for discrepancies between competing models; identifying which model is used in an explanation; testing models by experiment; ensuring that the relationship between the design of the experiment and the model being tested are clear; and restructuring or rejecting models in the light of conflicting evidence. The value of these behaviours and skills was discussed in general terms, not just in the context of Light and Colour. While students acknowledged the value of these behaviours as they related to defined content, they were noticeably less able and willing to involve themselves in discussing metacognitive learning behaviours in any general sense. By chance, the next unit was dramatically different. It dealt with training students to use microscopes, and construct wet and dry mounts, according to lengthy sets of printed instructions. This new content had a narrower focus and a lower cognitive and metacognitive demand than that of Light and Colour. There appeared to be less necessity for a broad-based metacognitive approach. In fact, the classroom activities meant that different types of learning deficiencies from those in Light and Colour were likely to be revealed in the students. On analysis, the two learning tendencies (Baird & White, 1982) which seemed especially relevant to this new content were Impulsive Attention (focussing on only part of the instructions) and Premature Closure (submitting work in ignorance that some tasks have

not been done). Training was concentrated on these tendencies. They were discussed, the students were warned that they may display them, and each practical report was marked and returned rapidly. The students were concerned when many of these reports were judged to be incomplete (which cost them marks) even though they had genuinely tried to heed the warning. They were receptive to suggestions for positive strategies to overcome these deficiencies.

There was another, unexpected outcome of this substantial change in the type of metacognitive learning being promoted. For the first time, some students began to understand what PEEL was attempting to do. Until then, PEEL had meant, to them, the diary tasks referred to earlier. They had found discussions about the general nature of active learning to be boring, irrelevant and at least partly unintelligible. Seeing PEEL linked to content and classroom activities in two quite different ways helped them to generalize and to begin to appreciate some overriding ideas of PEEL, such as the differences between active and passive learning, and the nature of the processes of monitoring and control of learning.

The effects of new content were observed several more times that year - new topics meant a change in the type of learning deficiencies displayed and hence a change in the type of strategies for promoting, monitoring and controlling active learning. This assisted students' understandings of the general goals of the project.

Conclusions and implications concerning the dependence of metacognitive training on content

It now seems that adequate metacognition derives from a general attitude to, and conception of learning but does not derive from the application of general, relatively content-independent strategies, based on a standard set of evaluative questions. It further seems that the process by which these general attitudes and conceptions of learning arise is by a process of induction following from consideration and reflection about prior content-dependent metacognitive learning experiences. These experiences should have demonstrated the deleterious effect of specific learning tendencies on performance, and should have provided practice at overcoming them.

In fact, when students are being introduced to, and trained in, metacognition, a general strategy appears to be counter productive for several reasons. Firstly, a general strategy is more difficult for teachers inexperienced with the innovation to present effectively. Secondly, it does not appear as fruitful to the students as strategies more closely linked to the content. Thirdly, students need to see a range of types of metacognitive behaviour before they can understand the general principles of active learning.

Hence, it seems that each topic and its typical activities should be analysed in

advance to determine which poor learning tendencies are likely to arise. It may be helpful for metacognitive training if topics are sequenced in order to allow a range of these tendencies to be displayed. The most appropriate time to first raise more general issues of awareness and control of learning is after the students have experienced a range of specific applications.

MOVING CHILDREN'S SCIENCE TO SCIENTISTS' SCIENCE

Not only is content an important consideration with respect to organizing and sequencing metacognitive training, but it also needs to be evaluated in terms of organizing and sequencing attempts at changing conceptual frameworks.

There have been several teaching strategies proposed which stress the importance of identifying and working from students' prior views (Childrens' Science). Osborne and Freyberg (1985) reviewed several and offered another. Each of these strategies has involved a single general sequence. Several of these (e.g. Osborne and Freyberg, Erikson (1979), Nussbaum and Novick (1982)) suggest that the presentation of right answers be delayed while Children's Science is restructured into Scientists' Science by a process of cognitive conflict or challenge. At Laverton, attempts have been made to teach a wide range of science topics from a Children's Science perspective. Sequences of the type proposed by Osborne and Freyberg have been found to offer useful guidance for designing effective strategies in a number of topics such as Light and Colour, Mechanics and Electricity. In these topics, it has been possible to establish consensus with the students as to the (usually narrow) range of views in the class, and then test the ability of these views to predict and explain a range of situations suggested by both the teacher and the students. This has frequently resulted in students restructuring their views to a position closer to Scientists' Science. Compelling situations are ones where the Children's Science demonstrably fails; in particular, it is important that it predicts an outcome quite different to what actually occurs. The Scientists' Science being taught must, of course, correctly predict the outcome without needing to call on extra information. Situations where the Children's Science merely does not predict any outcome, or cannot explain what did occur as clearly as does Scientists' Science have been found to be much less powerful instruments for change.

This difference in outcome appears to be the reason for the failure of teaching sequences similar to those described above in a number of other topics; when teaching Heat, Combustion, Photosynthesis, Respiration, and the Particle Model and its extension to atoms and molecules, it has not been possible to generate the scientists' model by challenging and reworking the students' views. It has been found necessary to present the

Scientists' Science relatively early in the unit, after the students' views have been identified and discussed. The students' views are not dismissed, but retained as a plausible alternative. Then the competing models are tested in a range of situations. In the topics listed above, it has been more difficult to generate student dissatisfaction with the Children's Science when Scientists' Science was not available for comparison. The teacher may be able to demonstrate the inadequacy of the students' views to the teacher's own satisfaction, but not to that of the students. This is illustrated by contrasting approaches taken by teachers of a Year 10 unit which focussed on some of the processes involved in the carbon cycle: photosynthesis, respiration, decay, fossil fuel formation and combustion. The students' views were readily identified. They:

- 1) consistently used non-conservation of atoms and mass as well as large-scale interconversions of mass and energy to explain these processes,
- 2) saw little need to use a particulate model of matter in their explanation,
- 3) ignored the role of colourless gases, and
- 4) were unable, even if asked, to use the concepts of atoms and molecules in a way which distinguished one from the other.

One teacher, who had successfully used a teaching sequence of the type proposed by Osborne and Freyberg in other topics, tried it again. She probed her class and reported back to them on the range of views present. A series of well-conducted discussions followed. The students were initially interested in discussing and debating alternative explanations. However, in the absence of compelling situations of the kind described above, these discussions achieved little except to demonstrate that the students' views did not explain all phenomena in an entirely satisfactory and internally consistent way. This may be enough to cause a scientist to search for a more consistent and powerful model, but few students saw a strong need for their explanations to be consistent across a wide range of phenomena. They were even less interested in the idea of persistently searching for the best explanation. Their models offered some explanation for most phenomena and they saw little purpose in abandoning them to search for a possible but unspecified improvement. As the discussions continued, the students became frustrated and disinterested. They wanted to see some progress - where was the teacher going?

A different approach was tried on the same content with another class of the same year level. The students' views were probed in the same way and a summary of the results reported back to the class. There was sufficient discussion to ensure, firstly, that it was quite clear what the range of views was, secondly that the summary did accurately describe their views, and thirdly that these views were quite reasonable and did apparently explain a range of situations. This Children's Science was not dismissed, but the chemists'

model was then presented as an alternative explanation. The two models were then tested in a number of situations. A few of these were laboratory experiments, more were real world phenomena with which the students were already familiar. Using this approach, the students were now aware of the conceptual destination. Instead of practical situations being just a test of their views (which often could explain them), the emphasis was on a test of both views and which one offered a better explanation. This was a little easier than asking students to abandon a relatively satisfactory explanation in the quest for an unspecified improvement. Moreover, by having complete descriptions of both models, it was easier to point out the superior consistency of the chemists' model. This also made it easier to raise the general issue of explanations being consistent across a range of phenomena.

Unfortunately, this teaching sequence, although superior for some topics, has one major drawback. The Scientists' Science, with its use of abstractions such as atoms and molecules, is readily recognised by students as being the teacher's preferred model. This can raise a serious obstacle to active learning - many students will just see the scientists' science as the right answer to learn and consequently not engage in any active retrieval, comparison and change of models. This occurred in the class described above. A number, perhaps a majority, of students accepted that the chemists' model looked a bit better than theirs. However, this judgement was made rather superficially with little systematic retrieval and restructuring over a range of situations. Instead, the students became impatient with the continued discussion by the teacher of their prior views - 'look, we know the answer - let's just practice that'. The teacher (Mitchell) suggested to the class that merely learning the chemists' model may prove inadequate in assessments which required explanations of new situations. He gave them a (multiple choice) item which had been done very poorly on the previous year's test, told them to do it with their notes open, and predicted that most of them would select an alternative that was in conflict with the chemists' model; in other words that they would draw on their original views. This prediction turned out to be only too true. This immediately generated a lively discussion about that particular situation. However, the students were still uninterested in a more general discussion: "Okay, that's the answer - we'll learn it." To overcome this, the strategy was repeated several times - old test questions were given, and coupled with a prediction from the teacher that the students would not draw on the 'right' answer they claimed to be able to learn from the notes. The students answered the questions with their books open, yet consistently drew on their prior views. This outcome was always discussed with them afterwards. The final task was a long essay in which only one student's answer was not in serious conflict with the notes on the chemists' model. The cumulative effect of this appeared to be quite powerful. Many students finally accepted

that simply reading and memorizing the notes was inadequate. They had to systematically contrast their views with the chemists' model on a point by point basis. Some good discussion ensued. Other experiences from other classes have been consistent with the results describe above. Teaching sequences where the scientists' science appears early have been necessary in some topics and apparently have generated some conceptual change. The experience has been that it appears more difficult to generate active learning and hence conceptual change in these topics than in ones where scientists' science can be delayed and reached by a process of cognitive conflict. However, this finding should be treated with caution. Different topics have different levels and types of cognitive and metacognitive demand. This variation in content and hence assessment makes direct comparisons between topics impossible.

Conclusions about the dependence of teaching for Childrens' Science on content and the implications for promoting conceptual change

The need for explanations and models to be the best possible and consistent across all situations is implicit but perhaps insufficiently explicit in many teaching styles and strategies. Students do not necessarily share these needs and they need to be discussed overtly. Topics such as Mechanics are potentially useful vehicles for establishing these principles. This is because it is possible to test nearly all alternative explanations, in concrete ways, over a wide range of situations. Hence, it is easier to demonstrate the problems which arise from using inconsistent explanations in different situations. We recommend that such topics be included in science curricula and taught from the above perspective.

The teaching sequences used at Laverton are imperfect and hopefully will be improved in the future. However, it seems unlikely that any single general sequence for restructuring Children's Science is possible. Once again, the teacher needs to analyse the content in advance to determine the best approach. Unfortunately, it is not yet entirely clear why some units are more suited than others to the approach suggested by Osborne and others. It is suggested tht it is insufficient to ask students to abandon their apparently satisfactory explanation for a particular situation in favour of another view merely because the second one offers what the teacher regards as a more powerful explanation (e.g. explaining rusting in terms of atoms and molecules instead of a continuous model). To the students, the teacher's explanation is more abstract and complicated, but not very much more useful than the one they already have. Often, the teacher's model does not have great predictive ability unless it includes a number of more advanced ideas. The increase in abstraction required by the chemists' model and its lack of predictive power in Years 7-10 may be powerful barriers to its adoption by students. Ideally, the teacher

needs to be able to find several situations where the Scientists' Science at the level being taught and the Children's Science predict clearly different results. It sometimes cannot be done, either because the two models usually generate similar predictions (as in Heat) or because they do not have great predictive power (as in much of the chemistry taught in Lower and Middle secondary schools). In these situations, it appears necessary to present the Scientists' Science early in the topic.

SUMMARY

There are already a number of important criteria upon which topics for inclusion in science curricula should be selected and sequenced. We have recommended two additional criteria: the topic's potential for effecting conceptual change, and its potential for generating metacognitive training. Among other things, Science curricula should foster intellectual development. Such development is often a slow process of change, where new experiences, skills and understandings build on, modify and extend existing ones. Thus, topics should be evaluated in terms of their relation to existing Children's Science and to the students' metacognitive abilities. Evaluation of the appropriateness of a particular topic in a curriculum sequence should be based on such factors as its conceptual concreteness, the number and breadth of models which can be invoked, the concreteness of corroboration of results, and its predictive power. Conjointly, evaluation should take into account the nature, scope and complexity of the associated metacognitive demands. If selected carefully, topics in the science curriculum will do more than progressively sample the universe of content areas. They will develop each students ability and desire to engage in effective, independent learning.

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TEACHING, LEARNING AND THE CURRICULUM
2: SCIENCE AND BEYOND

Judie Mitchell and John Baird

The Project for Enhancing Effective Learning (PEEL) at Laverton High School (Mitchell and Baird, 1985) is an attempt to improve the quality of classroom learning and teaching. The project has involved participant action-research. This means that the 10 teachers involved were in charge of their own professional development and the project in general: they were the source of most new innovations and modifications; they decided what to do and when to do it. Baird's research had been conducted in science classrooms, as had the other major source of ideas, the related research into alternative frameworks. However the Laverton science teachers had previously been strongly influenced by Douglas Barnes, a humanities teacher, on interpretive versus transmissive teaching. This paper will describe how some techniques associated with these three areas were exchanged, used and adapted between science and humanities classrooms.

THE WEEKLY MEETINGS

The PEEL project has important implications for teacher change. One is the necessity of an ongoing support structure, such as a weekly meeting. The teachers were timetabled off for one period per week. These meetings enabled the teachers to overcome problems which arose when the strategies which they had used as a starting point proved unworkable, and fostered the process of action-research to the extent that by the end of term one the teachers were beginning to develop their own strategies. These meetings enabled valuable collaboration among the teachers and, because of the size of the group, the cross faculty techniques could be rapidly trialled and improved or adapted. The power which the teachers came to feel over the destiny of the project was due mainly to this sharing of ideas which were 'owned' by them.

INTERCHANGE OF IDEAS BETWEEN SCIENCE AND HUMANITIES

Concept Mapping.

In this technique, the names of concepts are arranged on a piece of paper and lines drawn between them to show connections. Explanations of the connections can be written on the lines.

The English teachers made one modification. To be functional, a concept map of a novel had to include names of characters as well as concepts, and often the names of objects, if they symbolised concepts. The English teachers found this very successful, as it generated high quality discussion and analysis of the novel. Another successful variation included only the names of the characters. We called it a relationship map. The students had to link the characters by explaining the relationships between them. This required them to provide the concepts themselves.

Interpretive discussions.

These are whole class lengthy discussions based on Barnes' conception of the Interpretive teacher. The students are encouraged to give their views on certain concepts. The teacher waits longer than normal for an answer and encourages elaboration of answers. The teacher deliberately withholds the accepted answer or point of view and remains non-committal and encouraging. This has the effect of exposing the students' views and why they hold them. The teacher can then try to establish some way of linking their views to the 'right' answer or accepted viewpoint.

The English teachers had held plenty of discussions, but hadn't been in the habit of using an extended wait-time or of deliberately withholding the accepted point of view, in order to find out what the students thought. Student/student debate was not really encouraged unless the topic of the discussion was an open-ended one such as 'Drugs'. In fact, this was the only time they really had open lengthy discussions. English teachers usually didn't run discussions like this on concepts which arose in 'everyday' teaching. They had never really probed like this for views on what a piece of poetry meant or, even more interestingly, the concept of what poetry is.

We adopted an idea used by a Science Education lecturer at Monash. The question 'What is Poetry?' forms the basis of a session he runs with student teachers. He presents the student teachers with some examples of writing which include Shakespeare, doggerel, limericks, an inscription, a dedication etc. They are asked to decide whether or not each piece is poetry. The same idea was tried with a Year 7 class and a Year 9 class. Exploring views on such a large concept was a new experience for the teachers. They had assumed that everyone more or less agreed about what poetry was and the important thing for the teachers to do was to teach appreciation and understanding of poetry. However if

students had prior views about what poetry was, then these could possibly limit their ability or desire to understand examples of it. The students did have views on what poetry was, and were able to write down definitions. But these views were very vague and based on intuitive feelings rather than facts. And yet some of the students were very definite and dogmatic when it came to sorting out poems from non-poems. Their reasons tended to include such statements as:

Poetry sometimes rhymes, but it doesn't have to.

This is a poem because it's set out right.

This is a poem because it looks like a poem.

None of the students were able to identify rhythm as a factor. This, combined with the fact that their definitions were so open, led one group in the Year 9 class to the conclusion that any piece of writing could be called poetry. As they knew this was obviously not true, they called for help and the teacher pointed out that good poetry is based on a rhythmic use of words which is combined with other factors such as length of lines. The students were then coming close to being able to distinguish between poetry and prose.

The teacher of the Year Seven class held discussions about similar pieces of writing and most of the class came to an agreement, as part of a definition, that poetry could rhyme, but it didn't have to. However when the teacher asked the students to write a poem, the majority insisted that their poems had to rhyme. Perhaps the discussion had done nothing to shift their prior views.

Another interpretive discussion was held with a Year 7 Integrated Studies class on the topic Continents and Countries. Students in Year 7 have difficulty with these concepts. At Laverton, some attempt is made to address the idea of how the earth's surface is divided up, both physically and politically. The concepts are actually more difficult than they at first seem because they are not mutually exclusive. In other words, a country can be a continent as well. In initial discussion it became apparent that the students needed 'islands' as a term of reference. However the students used the word indiscriminately, even though they could provide a 'definition' (land surrounded by water). The students did not regard that definition as important. Several students often referred to landlocked countries as islands and were quite surprised when the teacher insisted that the word be used consistently. This is evidence of the language gap which often exists between teachers and students. Teachers have specific meanings for words and teach concepts according to those meanings. Students, as a general rule, or until a reason is pointed out to them, often do not see the point of having such specific meanings for words.

Prediction, Observation and Explanation.

In this technique in Science classrooms, students are shown the first stage of an experiment, and asked to predict what will happen, with written reasons. The students

observe and record what does happen and then attempt to explain any discrepancies which arise between their prediction and the actual outcome.

This was adapted in a Year Nine English class by stopping reading a novel and asking the students to predict the ending. Their written predictions were inconsistent with the clues given in the novel. They almost all opted for a 'happy ever after' ending. The next time it was tried the students were again asked to predict the ending, then read the actual ending and compare their ending with the author's. They had to comment on which one was the more realistic in the context of the novel. Once again most of them opted for 'happy ever after', but without exception commented that the author's 'less than happy' ending was the more realistic and gave sound reasons based on the characters' likely actions.

In Science this technique is very powerful because the students think they can predict the outcome of a given experiment. In English the impact was less dramatic (the ending is after all only the author's point of view), but it forced the students to become more aware of the characters and motives, and also to confront their own 'unrealistic' tendencies.

Alternatively, some of the techniques we initiated and developed in Humanities classrooms were taken up and adapted by Science and Maths teachers.

Student Question Asking.

An important technique in developing metacognitive behaviour is to encourage students to ask more reflective questions. It was one of the earliest successful strategies. It began in the humanities area, and ricocheted around the faculties. It also provided teachers with an opportunity to reward the students with some immediate payoff.

One of the first attempts occurred in a Year 10 Commerce class where the students were asked, at the end of a topic, to make up two questions on the topic, beginning with 'Why...?' and 'What if...?' The questions were excellent and the teacher typed them up and handed them back to the class to discuss. The students were extremely pleased with this recognition. Another teacher incorporated some 'Why...?' and 'What if...?' questions into an assignment in Integrated Studies at Year 7, including the instruction to the students to make up similar questions of their own. Students made up both factual questions and reflective questions. These were discussed and divided up by the class into what were called 'fact' and 'thinking' questions.

A Year 9 class was given an assignment on a novel, part of which required them to make up reflective, or open-ended questions about the book. Again the students' task was to try to think of questions which began with 'Why...?' 'What if...?'. This task was worth one-third of the marks. The teacher noticed that most of the students were asking purely factual questions, which did not relate to the level of their understanding of the issues in the novel. The teacher then developed some criteria to help the students determine what were factual questions and what were thinking questions.

Topic last lesson: _____		Date: _____
Topic this lesson: _____		
Task I had to do: _____		
How did you go? (tick (/) square)		
I remembered the last lesson	☐	I knew how to do it ☐
I knew what the topic was today	☐	I worked hard all lesson ☐
The work made sense to me	☐	I asked for help ☐
I asked some questions	☐	I finished the work properly ☐
I got some answers	☐	I checked that I had finished and read over my work. ☐
I knew what task to do	☐	

END OF WEEK SUMMARY	
Two important things I've learned are:	
(a) _____	
(b) _____	
One thing that still puzzles me is: _____	
Something I would like to know more about is: _____	
TEACHER COMMENT: _____	

Figure 1. Monitoring of learning sheet

MY WORK PROGRESS

WHERE I LOST MARKS	Title of work			
1. I didn't answer all the questions.				
2. I didn't finish all the work (a) I forgot or couldn't be bothered. (b) I didn't understand the work				
3. Some of my answers were wrong or didn't make sense.				
4. I left out some important things.				
5. I didn't write enough in my answers.				
6. I wrote too much, and some of what I wrote was irrelevant.				
7. My work was messy and untidy. It was not well organised.				
8. My spelling and punctuation were poor. (write in which, or both)				
9. It was not my best work. I could have done better.				
10. I didn't follow all the instructions properly.				

Figure 2. Where I Lost Marks Sheet

Writing Good Questions

Fact Questions

1. Your question can usually be answered in one or two words.
2. The answer is on a certain page in the book or notes.
3. The answer is either right or wrong.
4. The question usually starts with What, Where or When.

Partly fact, partly thinking questions

1. Your question usually requires a sentence or two answer.
2. The answer is not on any one page in the book or notes but if you've understood the work you'll know it.
3. The answer will be right if explained well and you've understood the work, but could be wrong.
4. The question often starts with How.

Thinking questions

1. Your question usually requires a paragraph answer.
2. The answer is not all provided by the book or notes.
3. The answer will always be right if it makes sense according to the book or notes and is explained well.
4. The question often starts with Why or What if.

The students applied these criteria and most of them succeeded in improving the quality of their questions. This technique, and these criteria, were then used by other teachers. Soon, the students were generating so many good questions that the teachers started to wonder what to do with them all. Several times teachers found themselves changing lesson directions and being led by the students' needs. Thus, the students' questions were acting as a stimulus for negotiation of curriculum. For example, in a Year 9 history class, the teacher showed a video and asked the students to write questions about anything they found puzzling as they watched. The class came up with 159 questions altogether. The teacher wrote all these out in no particular order and gave them back to the class. He asked them to classify them into content areas. No student considered this an onerous task, presumably because they 'owned' the questions. One student classified the questions so well that the teacher then used this student's scheme and thereby changed the way he presented the topic. Similarly, Year 7 Integrated Studies students read a passage from a history textbook on the beginning of the universe. They were then asked to write down questions on anything they didn't understand. When these questions were discussed it was found that many couldn't easily be answered. The students asked if they could research the questions and make presentations of their findings.

After hearing of these experiences, one of the Science teachers called for questions part way through a Year 10 unit on Forces and Motion. A number of students raised the

question of forces underwater and showed an interest in investigating this aspect of the content. The teacher then suggested to the students that they design and perform their experiments to test out their conflicting views. The results were so interesting that the teacher then abandoned the aspect he had intended to teach and concentrated on the underwater aspect. The teacher felt that this approach improved the unit, and intends to include this in the content of the unit for future classes. Some teachers decided to award marks for the quality of questions students asked during lessons. A science teacher introduced a question-asking component into his Year 10 science course assessment. Students could earn up to 10% of their term's marks by asking questions in class, and, to be fair to quieter students, for written questions handed in after the lesson. Most of these questions were discussed and answered either immediately or the next day. This recognition proved to be a further pay-off for the students.

Monitoring Sheets.

One of Baird's poor learning behaviours (Baird and White, 1982) was the inability of students to effectively monitor their own progress. We developed sheets which outlined 'good learning behaviours' (see figure 1) and asked the students to tick the boxes they felt applied to their own behaviour in that particular lesson. The students filled them out every lesson and the teacher wrote a comment in reply once a week.

There were a number of problems with this technique. It was time-consuming and we found that often we did not want to interrupt what the students were doing. We found that the students became careless, or were too rushed, and often just randomly ticked boxes, to get it 'out of the way', or because they couldn't be bothered thinking about it. The teacher replies were time-consuming and, although the students read them with obvious interest, we felt they were of negligible value. The major problem with these sheets was that they did not provide sufficient feedback to the students about how they were going and they were not able to see clearly where their areas of weakness lay, so they could do nothing to try to improve or to compensate. Although other formats were tried, none was successful until a 'Where I lost Marks' Sheet was devised. Students kept this sheet in the back of their folder and filled it in each time they received a marked piece of work.

The sheet requires the teacher to explain in some detail why marks are lost. Because of this, it has proved more useful to students as they are able to see how they are going and whether or not they are repeating certain mistakes. They are then able to do something about it. Similar sheets specific to Science and Maths were developed subsequently.

PARTICIPATION - NEGOTIATION?

One of the outcomes of these techniques has been increased student responsibility

for determining the content of, and activities during, lessons. Boomer (1982) sets out a model of curriculum negotiation which has been adopted by a number of schools. Boomer's model involves teachers and students asking four questions about a content which has already been selected by teachers and students. These questions are:

- 1) What do we know already?
- 2) What do we want, or need, or find out?
- 3) How will we go about finding it?
- 4) How will we know, and show, that we've found out when we've finished?' (p.8)

He suggests that the negotiation occur at the beginning of the unit.

At Laverton negotiation has frequently occurred naturally and spontaneously after a unit has begun, and after the students have acquired some understanding and experiences in the area. Among other things, the application of the technique described above resulted in the students often asking many reflective and evaluative questions, more than they would have, or probably could have done without the training in active learning. These questions formed the basis for the negotiation.

The results at Laverton suggest that, if negotiation is to achieve a useful role in the curriculum, we need first to train students to be more informed and more purposeful about their learning. Thus, effective negotiation requires more than increased student participation. It requires that students be trained in the skills necessary to collaborate informedly in the negotiation process. This training is for enhanced knowledge, awareness and control of the learning process - training in metacognition.

This paper highlights some findings regarding such training. These findings bear on both the process and outcome with respect to the goal of more informed, purposeful students. For process, the findings have underlined the value of cross-faculty group action-research in the development of techniques for training for metacognition. For outcome, they show that metacognitive students are capable of contributing effectively to their own education.

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Research In Science Education, 1986, 16, 159-168.

SEX DIFFERENCES IN SCIENCE EDUCATION IN A DEVELOPING COUNTRY: KENYA

Nicholas Twoli

There is a great deal of evidence which suggests that girls do differ from boys in terms of their achievement, attitude, aspirations and expectations in science. In most societies, girls enroll in fewer science courses, perform fewer science activities, perform less well and express more negative attitudes towards the physical sciences and are less likely to embark on a career in science.

Like many other developing countries, Kenya places great emphasis on science education. The government has adopted the classical human capital position whereby expenditure on scientific and technical education is seen as a form of investment. As such, it is concerned to ensure that there is a good 'yield' of scientific knowledge from its investment in Science Education. Given what is known of sex difference in science achievement and subject choice from studies in advanced societies (Comber & Keeves, 1973; Haertel *et al.*, 1983; Steinkamp & Maehr, 1983) it seems likely that there will be significant differences in Kenya between boys and girls in secondary schools. The evidence from advanced countries would lead one to expect that the performance differences would be most pronounced on science tasks demanding spatial and mathematical abilities and least on tasks requiring verbal (descriptive) abilities. However, as a context of human development, Kenya and regions within it are different from Australia, the United States and the United Kingdom. The precise nature of the differences in science achievement between girls and boys remains unknown in Kenya, while in developed countries "studies on the topic are many, but the actual findings are inconsistent, even contradictory" (Steinkamp & Maehr, 1983). This study attempts to identify the nature of sex differences in science achievement in the developing country, including differences in physical science and biological science, and science-related developed abilities (such as mathematical, spatial, verbal and experimental abilities). There is also an exploration of differences in the students' attitudes, aspirations and science-related experiences. At the school level, the effects of resources and teachers on science achievement are examined.

PREVIOUS RESEARCH

Differences between the sexes in science achievement test scores have not typically been large when compared with differences within the sexes, and there has tended to be considerable overlap in boys' scores and girls' scores. However, there has been virtual consensus in the literature that, as a group, boys outperform girls in science in most countries (Comber & Keeves, 1973; Kelly, 1978; Steinkamp & Maehr, 1983). The typical pattern in major science achievement data has been that sex differences are less pronounced at the elementary level but increase with age, reaching their maxima at adolescence. This has been partly attributed to preadolescent boys' attempts to enhance their manliness by achieving in science, whereas many girls in that age group attempt to enhance their femininity by not achieving in science (Kelly, 1978; Steinkamp & Maehr, 1983). The magnitude of these differences has not been uniform across subject areas. In virtually all sets of data available, boys clearly outperformed the girls in the physical sciences, especially in physics; yet in the biological sciences the boys' advantage has been less apparent and typically small (Comber & Keeves, 1973; Kelly, 1978; Steinkamp & Maehr, 1983). The low performance by girls in physics has been explained in terms of their perception of physics as a masculine subject, the fact that the subject lends itself to out-of-school activities and their low level of mathematical and spatial abilities (Kelly, 1981; Ormerod *et al.*, 1975; Steinkamp *et al.*, 1983).

Origins of sex differences have been linked with the biological (genes) variables, socio-psychological influences and school based variables. Kelly (1981) summarizes the origins of sex differences in science in three hypotheses. The most widely advocated hypothesis is the 'culture hypothesis' which suggests that girls achieve less well than boys in science because society does not encourage or expect girls to achieve as well as boys in science. The second hypothesis is the 'attitude hypothesis' which suggests that girls perform less well than boys in science because girls have unfavourable attitudes towards science. If students work enthusiastically at subjects they enjoy, this extra work is likely to result in better achievement. The third and final hypothesis explaining differences in achievement is the 'school hypothesis' which suggests that science is presented in schools in a way more suited to boys than girls.

Differences in attitude towards science are larger in some subject areas than others. Females have more positive attitudinal orientations towards biological sciences while males lean towards the physical sciences (Comber & Keeves, 1973; Kelly, 1978; Ormerod *et al.*, 1975; Steinkamp & Maehr, 1984; Walberg, 1967). This differential orientation in attitudes towards science has received some plausible explanations. Females' more positive orientation towards biological science is that it deals with life

processes which are related to the female anticipation of a maternal role. The other explanation is that the learning of biological science revolves around the verbal propensities of girls and thus serves as a vehicle for girls' increasing interest. Males' positive orientation towards physical science has been attributed to its out-of-class activities and also to cognitive ability. To feel positively towards a subject, one has to actualize one's ability through achievement in that subject. Since boys are known to do better in physical science, they will also hold more positive attitudes towards this subject.

Variations in magnitude of sex differences in affect towards science across countries is interesting. Apart from Israel, where girls have more positive attitudes towards science than boys, in the rest of the countries boys have a greater liking for science than girls (Kelly, 1978; Steinkamp & Maehr, 1984). The greatest differences, surprisingly, were found in the more technologically developed countries (Australia, Japan, Sweden, US, UK). Another disturbing finding, based on US data, is that sex differences in attitude towards science are on the increase (Steinkamp & Maehr, 1984), despite recent efforts to remove stereotyping labels in schools.

The evidence from research in developed countries seems to suggest that the direct effect of schooling, and in particular the effect of teacher quality, is, at most, ambiguous (Guthrie, 1982; Ornstein, 1984; Saha, 1983). In developing countries, however, the findings seem to speak with one voice, that is, school and teacher variables are important determinants of school achievement. An extensive review of literature by Huse'n, Saha and Noonan (1978) supports the contention that teacher variables are important factors in explaining variance in student achievement in less developed countries.

METHODS

Subjects

The subjects were of two categories: 1) 424 Form Four students (0 level or Year 11 students) comprising 215 boys and 209 girls, in Kenya schools, who were taking the three science subjects - Physics, Chemistry and Biology. 2) Form Four science teachers in the selected schools plus other science teachers teaching Form Four students in non-selected schools, making a total of 144 teachers.

Schools

With very little exception, schools in Kenya are single sex schools. Ten boys' schools and 14 girls' schools were used as sampling units. The geographical distribution and type of the schools was also considered in selecting a stratified random sample of schools. Schools in Kenya are characterized by a 'class' system, with three distinct classes of school: National (high class); Government schools (second best); and private schools (most

disadvantaged). There were 8 urban and 16 rural schools; and 5 National, 15 Government and 4 Private schools in the sample.

Research Instruments

a) **Dependent Variables:** There were two types of achievement tests -

(i) multiple choice items (40 items) which comprised 20 physical science items and 20 biology items. The items were selected from the IEA Science Tests (Comber & Keeves, 1973). The selection of items gave special consideration to items requiring spatial ability related tasks (graphs), mathematical, practical and verbal (descriptive) tasks.

(ii) Essay questions: there were three questions, one from each of the three science subjects - biology, chemistry and physics.

b) **Independent Variables:** These were obtained from questionnaires for teachers and students. The students' questionnaires consisted of attitude, aspiration and science experience scales, each scale consisting of a number of items relating to physical science and biology. The attitude scale consisted of three sub-scales: (i) like physical science (or biology), (ii) use of physical science (or biology), (iii) masculine-feminine feelings towards physical science (or biology). The aspiration scale comprised four items related to physical science and four items related to biology. The science experience scale was composed of 33 items with subscales: (i) observed (ii) visited (iii) used.

The attitude and aspiration scales were mostly IEA (1973) items with slight modifications to suit the Kenyan situation. The reliability coefficients of the original scales range from .72 to .80. The science experience activities scale was adopted from the NAEP scales which had reliability coefficients ranging from .75 to .82.

The teachers' questionnaire contained several items designed to measure teachers' attitudes, expectations, experience, certification, their teaching and assessment methods. The same questionnaire also provided for teachers' responses regarding their school resources such as laboratories, textbooks and teaching staff in science subjects. The questionnaire was based on the study in one of the African countries, Botswana (Husén, 1977).

RESULTS

The means and standard deviations for the components of the Achievement Test are presented in Table 1. Results show that boys outperformed girls on all components of the Achievement Test. The superiority of boys in mathematical, experimental and spatial

related questions (which were mainly interpretation of complex graphs) was expected. The surprising result was on verbal or descriptive questions, where girls were expected to take advantage of their language ability and do better than the boys. It is noted, however, that the difference in performance between boys and girls on verbal questions is quite small, and this narrowing of the gap could be attributed to the girls' language ability. Worthy of note also is the general performance on the mathematical and spatial components of the Achievement Test. Compared with the other components, the general performance by both girls and boys was less impressive. This might be an indicator that students usually find difficulty in science problems that call for mathematical and spatial related abilities. One of the main interests was to compare the performance of girls and boys in biological and physical sciences. As expected, the boys ($\bar{X}=18.66$) outperformed the girls ($\bar{X}=14.81$) by about one standard deviation. It was thought that this pattern would be reversed in biological sciences, but again the boys performed better than the girls. The gap, however, is much more reduced in this case.

TABLE 1
Performance on components of the Achievement Test and the Grand Total

Achievement component	Max Score	Boys		Girls		t
		mean	SD	mean	SD	
Mathematical	(11)	5.80	2.61	4.45	2.11	6.04*
Experimental	(10)	6.38	1.53	5.80	1.60	3.86*
Spatial related	(10)	5.69	2.60	4.31	2.61	5.41*
Verbal (descriptive)	(27)	19.78	3.43	18.20	3.50	4.66*
biology	(26)	19.05	3.16	17.93	3.04	3.71*
physical science	(32)	18.66	5.88	14.81	5.30	7.06*
Grand total	(58)	37.72	7.94	32.72	7.27	6.74*

* $p < .001$ $df = 422$

The other aspect of sex differences which was investigated was in relation to attitudes, aspirations and science related experience (Table 2). Boys expressed more favourable attitudes than girls to physical science, and also had higher aspirations for higher education in physical science. The results were different in attitudes to biology and aspirations for higher education in biology. Although the results were not significant, the girls expressed more liking and higher aspiration for biology.

There was a significant difference in science related experiences, where boys ($\bar{X}=28.02$) recorded a higher level of science activities than the girls ($\bar{X}=25.82$), by about 2 standard deviations.

TABLE 2

Means and Standard Deviations of Attitudes,
Aspiration and Science Related Experiences.

Name of Scale	Boys		Girls		t
	mean	SD	mean	SD	
Like physical science	11.17	1.60	9.35	1.88	10.74*
Like biological science	11.37	1.37	11.46	1.04	.81
Aspiration for Ph. Sci.	10.95	1.47	8.95	1.79	12.64**
Aspiration for biology	10.94	1.47	11.10	1.26	1.10
Science related experience	28.02	0.98	25.82	1.11	4.15*

* $p < .01$ ** $p < .001$ $df = 422$

Some school and teacher variables in boys' and girls' schools showed some significant differences. There were, however, a number of teacher and school characteristics that were investigated but showed no significant differences. These included teachers' attitudes, teaching methods and school learning time. The variables that showed significant differences in boys' and girls' schools all favoured the boys' schools (Table 3). The greatest difference was recorded in teacher expectations of their students in academic achievement which included assessing students' ability to study science at a higher level of education. School science resources, which mainly considered laboratories, science textbooks and science teaching staff, also showed a very significant difference.

TABLE 3

Differences in Teacher Variables and School
Resources in the boys' and girls' schools

Variables	Boys schools (70)		Girls Schools (74)		t
	mean	SD	mean	SD	
Teacher variables:					
Teaching experience	8.09	0.48	6.61	3.97	2.91*
Prof. training	3.61	.84	3.40	0.99	3.69*
Expectations	42.43	16.55	28.47	14.76	5.33**
School science resources	8.96	1.48	8.42	1.51	3.16**

* $p < .05$ ** $p < .01$ $df = 142$

To determine the relationships and the effects of the students, teachers and school variables for girls and boys on achievement, a regression analysis was performed, with science achievement as the dependent variable. In order to get a correlation matrix, two dummy variables (National and Government schools) were created from type of school variables, with private school as the exception. More composite variables were created to

give more comprehensive results in analysis. For purposes of comparison, the unstandardized regression coefficients (Bs) are used.

Examining the correlations of the student, teacher and school variables with achievement (Table 4), it is observed that school resources, aspiration for physical science and teacher expectations in physical science and biology have fairly high values. Modest correlations are observed with school type, particularly National school, science experiences 'observed', science experiences 'visits' and professional training. Surprisingly low correlations were observed with urbanicity and teacher experience.

TABLE 4
Unstandardised Regression Coefficients for the Effects of Student,
Teacher and School Variables on Science Achievement for boys and girls.

Variables	r*	Bs for boys	Bs for girls
School characteristics			
National schools	.32*	5.98*	5.80*
Government schools	.13	10.38**	1.60
School science resources	.43*	9.27*	3.38*
Urbanicity	.04	4.95*	1.36
Student variables			
Attitude (Ph.Sc.)	.30*	.20	.27
Attitude (Biol)	-.11	-.28	1.09
Aspiration (Ph.Sc.)	.47*	1.38**	1.33*
Aspiration (Biol)	.06	.30	-.42
science Exp. (obs.)	.18	.13	.16
science exp. (usage)	.08	-.35	.60
science exp. (visit)	.21*	-1.20	.28
Teacher characteristics			
Teacher experiences	.05	.11	.30
Professional training	.32*	7.97*	.47
Teacher expectation (Ph)	.42*	.03	.24*
Teacher expectation (Bio)	.46*	.23	.10
Adjusted R ²		.29**	.39**

* p<.05 ** p<.01

r* is the correlation with achievement for the whole sample

r>+.20 would be significant at .05 level (allowing for design effect)

To compare the effects of the variables on the boys and on the girls, two separate regressions were performed. School variables have the greatest effects on both the boys and the girls (Table 4). Nevertheless, there are substantial differences in the degree to which the effects of urbanicity affect boys and girls. The effects of urbanicity on the boys outweigh that of the girls.

One possible inference which can be drawn from this result is that boys are more resourceful and better predisposed in an urban environment with respect to learning science and therefore benefit more in this environment than girls. Among the student variables one single variable that stands out as having significant effects on achievement

for both boys and girls is aspiration, especially aspiration for higher education in physical science. Science experiences, collectively have greater effects on achievement for the girls than for the boys. This is not surprising considering that most of the girls' activities are more school based compared with the boys. Some teacher variables showed some significant effects on science achievement for boys and girls. Professional training of teachers showed positive and significant effects on achievement for the boys as compared with the girls. On the other hand, teacher expectation in physical science showed positive and significant effects on achievement for the girls as compared with the boys. In general, teacher expectations of students in science education had greater effects on achievement for girls.

DISCUSSION AND CONCLUSION

This study has produced findings which in most cases support the previous work. Boys outperform girls in science, with the widest gap appearing in physical science and the narrowest in biological science. This supports the conclusions reported by Gardner (1974), Stinkamp and Maehr (1983) and others. The superiority of boys in physical science could be explained in terms of how the subject is learnt. Physical science is more sensitive to out-of-school learning. Boys in western society are more likely to be involved in repairing appliances, tinkering with engines and engaging in investigative activities (Walberg, 1967), whereas girls are more likely to play 'house', care for plants and pets. In a developing country in Africa, like Kenya, boys are most likely to be involved in outdoor activities such as herding animals, hunting and fishing, while girls' activities are likely to be domestically oriented, involving child minding, washing and cooking. The mathematical component could be a contributing factor to the wide gap in the science achievement for girls and boys in physical science. Given that boys have higher developed mathematical ability (Eshiwani, 1984) after adolescence, they would integrate their mathematical ability with the learning of science to enhance conceptualization. The surprising result in the achievement section was the girls' lack of superiority in descriptive areas and areas that call for comprehension. Given that girls have higher ability than boys in verbal ability, it was expected that the girls would transfer their language ability when it came to descriptive tasks in science. This seems not to be the case as the girls did less well on the descriptive part of the achievement test. Some explanations can be given to this result. One such explanation is that English, which is the medium of instruction in Kenyan schools, is a foreign language, and the mastery level of the English language reached by the girls might be of no significant advantage. The other possible explanation is that, in science one has to conceptualize the scientific knowledge before the language can be of effective use.

The attitude and aspiration patterns were similar to the earlier findings, where boys showed more motivational orientation towards physical science, with the girls showing more positive motivational orientations towards biology. The apparent remoteness of physical science from girls' everyday concerns has been one explanation for girls' low orientation towards physical science. The masculine image of physical science has been proposed as another explanation for girls' lack of motivational orientation towards physical science. The boys' higher aspiration for further science education could be linked to the widespread concern about employment prospects and the belief that the man in the house is the 'bread winner'. In recent years the Kenya government has emphasized and promoted job opportunities in the sciences with the aim of attracting and training the more needed technicians in the country.

The school effect variables, mainly teacher quality (and behaviour) and school resources were found to explain substantial variance in science achievement. These findings anchor well with those of Heyneman (1976) who argued that the determinants of science achievement in less developed countries are different from those in the developed countries. Drawing in the first instance on his own research in Uganda, and secondly on his analysis of IEA data, Heyneman contends that measurement error and mispecification of achievement models used in the previous research account for much of the ambiguity in findings from the developing countries. His research suggests that school and teacher variables are more important in explaining variables in student achievement in developing countries.

It has been noted that the pattern of achievement by subject areas in science and the motivational orientation of girls and boys towards science is very much similar to the pattern found in the developed countries, with the boys outperforming the girls and expressing more positive attitudes towards science. The main difference, however, may lie in the effects of the school variables which proved major determinants of science achievement in the developing country, unlike the developed countries where the school variables account for only a modest proportion of variance.

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Research In Science Education, 1986, 16, 169-174.

LISP (ENERGY) - THE FRAMEWORK

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INTRODUCTION

The Science Education Unit at the University of Waikato (SERU) has completed two three-year research contracts with the N.Z. Department of Education: the Learning of Science Project (LISP) and the LISP (Primary). The third project, LISP (Energy), began in 1985 and is exploring teaching and learning of energy in primary and secondary schools. This paper gives an overview of the project, outlines some major features of the research design and offers some preliminary conclusions.

Why LISP (Energy)?

The first project explored teaching and learning of science by 11 to 14 year olds in N.Z. schools, the second project looked at science for 7 to 10 year olds and developed interactive teaching (Biddulph and Osborne, 1984) as a means of addressing some of the difficulties encountered. In the planning of the third project, consideration was given to transferring this interactive teaching model from primary to secondary school. Since the topic of energy features considerably in both curricula, it was seen as the possible vehicle for this transfer.

THE PROJECT RESEARCH QUESTIONS

The contract requires consideration of the following questions:

1. What are the present transmitted and received curricula on energy and its related concepts in primary and secondary schools?
2. What are the teachers' and students' ideas about energy and how do these contrast with the currently accepted scientific view?
3. What are the reasons for, and the implications of, disjunctions between these various views for learning, teaching and the syllabus? What are some practical solutions to the perceived problems of teaching and learning related to the topic of energy?

4. What changes in instructional strategies are evident as a result of the solutions suggested under 3 above?

The Introductory Strategy

Planning for LISP (Energy) involved formal and informal discussions with many science educators and culminated in a two-day Brainstorming Conference (May 1985). The following conclusions were made:

1. The wealth of data on children's alternative frameworks of energy (some key references are (Stead 1980), (Driver and Millar, 1986) reviewed as the first Working Paper of LISP (Energy) (Welch 1986) needs little further elaboration.
2. Existing concepts of energy have the following features:
 - (a) Vague, divergent and opposing views are held by (and within) groups of scientists, teachers and students.
 - (b) Energy is frequently treated as a material substance, both deliberately (since abstract concepts are regarded as too difficult to teach) and inadvertently (when fuels are described as being energy - coal is energy, etc.).
 - (c) The principle of Conservation of Energy is a difficult concept which is confused with fuel conservation. Usage such as "energy is lost as heat" contributes to their difficulty.
 - (d) A common transmitted and intuitive idea, that energy is stored in matter in definable amounts, may not be helpful in teaching and learning across the disciplines of school science.
3. Rather than accepting all the existing concepts of energy the project would develop and explore a unified framework.
4. Alternative frameworks held by teachers and their problems with conceptual change would be a significant component of the research.

The Guiding Principles

The project team considered that some of the points in 2 and 3 above could be addressed if a set of proposals (the "guiding principles") was developed. These guiding principles were intended to assist teachers at all levels and in all disciplines in their consideration of energy topics. They were not intended as a definition of energy to be taught to students. Essential criteria for the guiding principles (referred to as G.P.'s) were:

- (i) Energy is seen clearly focused only when a defined change to a system is being considered.
The familiar usage of "stored" energy suffers from a serious ambiguity until it is clear what happens next. In probing this idea we have often asked educators to consider a number of objects on a shelf, for example a battery,

a container of hot water, a lump of sodium, some sugar, some TNT, a rabbit, some wood. If all these objects are of equal mass, then until what happens next is described, i.e. until a change is defined, the "stored" energy in each is ambiguous. Should each drop an equal distance, was the "stored" energy the same? What if each was combusted?

- (ii) In defining this change, the boundaries or limits to the system need to be described. Only then can descriptions of changes be fruitful.
This approach accepts that system changes can have matter and energy inputs and outputs and that these can be described. The approach avoids the procedure - common to, but not exclusive to, biologists - in which all energy considerations are traced to the sun, with boundaries for explorations and measurement being dissolved into a cosmic view.
- (iii) When considering defined changes to defined systems, the initial consideration should be of observable and ultimately measurable changes. The development of energy concepts would follow this consideration. This would often result in an explicit separation of material changes from energy changes.
- (iv) The principle of conservation of energy requires that when energy changes in form, the total amount of energy remains constant.
- (v) The approach is deliberately Newtonian as is judged appropriate for primary and secondary teaching and learning.

We formulated the following set of guiding principles using these criteria:-

LISP (Energy): Criteria

There appears to be a great deal of confusion about energy. Not only do children have everyday meanings for the word 'energy', but scientists in different disciplines may not agree amongst themselves on a definition of energy. We have formulated 'guiding principles' which focus on changes to systems. We hope this will present a view of energy helpful to teachers in their planning and teaching of primary and intermedite science lessons. The principles are not a definition of energy and need never be stated directly in the classroom. The principles are best explained using examples of everyday situations and we will look at two situations: a log fire, drying the washing.

- 1. It is necessary to analyse systems undergoing change to clarify the concept of energy.
 - 1.1 The system may be open or closed.
- 2. For such an analysis of a system undergoing change, it is necessary to describe the initial and final conditions by specifying for the components their:

- (i) relative positions
 - (ii) chemical composition
 - (iii) temperature
 - (iv) speed
 - (v) state (solid, liquid or gas)
 - (vi) mass
3. To explain the changes described by comparing the initial and final conditions of the system, and to more fully describe the change, it is necessary to introduce the concept of 'energy' as a non-material factor in the change.
 4. Energy exists in a variety of forms, e.g. light, sound.
 5. When energy changes in form, the total amount of energy remains constant.

The Guiding Principles and Teachers

Our first discussions and interviews with teachers suggested that these G.P.'s provided a conceptual conflict for most teachers. A research programme involving teachers as participating researchers was begun. Three teachers, judged highly competent and supportive of the LISP approach, (a chemist, a physicist and a biologist) agreed to join a programme in which:

- (i) their concepts of energy were explored in an interview
- (ii) a day was spent in discussion of the G.P.'s
- (iii) on a second day a few weeks later, this discussion was continued and the next phase (in which each of these three met with a group of six other teachers) was planned.
- (iv) each teacher discussed the G.P.'s with six other teachers on two days (separated by two weeks).
- (v) a major report back session on the influence of the G.P.'s on teaching will take place in July 1986.

The material so far audiotaped has yet to be transcribed but some preliminary observations seem worthy of comment since they reveal aspects of what may be described as teachers' alternative frameworks of energy, and the difficulties involved in conceptual change.

The Static System View of Energy

The G.P.'s consideration of systems undergoing a defined change challenges the concept of stored energy in static systems (resolution of this conflict comes from realisation that the term "potential energy" implies a defined change". Teachers who began with stored and potential energy as a major feature of their framework were clear in expression of their difficulty with the G.P.'s. After discussion they expressed a readiness to modify their view, and to consider systems undergoing change.

Changes vs Changing

This declared preparedness for conceptual change can be apparent rather than real. This is likely to be the case when the analysis of changes to systems resulted in statements about form(s) of energy changing to other form(s) (so that for a person on a slide, "gravitational energy is changing to kinetic energy and heat"). The real change has been converted to an instantaneous snap-shot in which the only change occurring was energy transformation(s) (sometimes seen as causal of the overall process). The real change(s) (the person changes height, gains speed, the slide and contact becomes hotter) were viewed as elementary and already familiar to students. Throughout our explorations of simple systems undergoing change, we have frequently discovered an extreme reluctance to explore and document the observable. In this framework energy can become an invisible and mystifying causal agency of change.

The following extract from a teacher's discussion of a practical exercise illustrates this point:

"Now you should have written a conclusion on that. Something that you observed about the energy changes, and I know someone who observed that it went from the chemical energy of the air to gravitational potential to kinetic, gravitational to kinetic.... Someone observed that sort of thing. You write down what you observed."

BOUNDARIES TO CHANGE

The final general feature of alternative frameworks of energy concerns the definition of boundaries to systems undergoing change. When this definition is explicit, analysis of real change is both possible and valuable. The alternative framework in which energy is traced back to the sun results in a confusing and increasingly evanescent concept of energy.

CONCLUSIONS

Although the formulated guiding principles may be too detailed, and are not readily accessible to teachers, the main features have proven to be of vital importance in our discussions with teachers. These are:

- (i) that establishing boundaries to systems undergoing change is a vital consideration.
- (ii) that real, and not infinitesimal, changes should be explored and carefully described. In this way the consideration is of observable phenomena rather than invisible constructs.

Acknowledgments

The authors acknowledge the help of their colleagues in SERU, who have contributed

to the many discussion leading to the G.P.'s and their investigation, the advice of members of the Brainstorming conference, and, as always, the support of teachers and students in the Waikato region and beyond.

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Research In Science Education, 1986, 16, 175-183.

LISP (ENERGY) - SOME PRELIMINARY FINDINGS

Valda Kirkwood, Malcolm Carr and Jane McChesney

INTRODUCTION

This paper begins with a brief outline of two aspects of LISP (Energy) - a 3 year research project funded by the N.Z. Department of Education and being conducted in this unit (1985 - 1988). These aspects are the detailed interviews (described below) and the analysis of curriculum materials distributed by the N.Z. Department of Education for guidance in the teaching and learning of the concept, energy (Phase 1). The paper then reports in more detail on the intensive classroom observations of teaching an energy topic (Phase 2), referring to the interviews and the curriculum material in this report.

PHASE 1 : INTERVIEWS

Towards the end of 1985 Project Officers in LISP (Energy) conducted interviews with primary teachers (15), intermediate teachers (5), primary science advisers teachers' college science lecturers (3) and Department of Education officers (5). Those interviewed had replied to a letter inviting participation in the Project or were approached personally by the interviewers (i.e. the Project Officer and Jane McChesney, a temporary project officer with LISP (Energy)). The interviews explored opinions on the place of energy in the N.Z. science curriculum, on the difficulty of teaching and learning about energy, and sought an outline of the concept of energy held by the person interviewed. Some interviews also discussed the ideas developed by LISP (Energy) (Carr, 1986).

The audiotaped interviews have been transcribed and the large amount of data is being analysed. Some preliminary analysis will be referred to later in this paper.

PHASE 1 : ANALYSIS OF CURRICULUM MATERIALS

The documents analysed were the N.Z. Infant to Standard 4 Science Syllabus and its accompanying unit books, the N.Z. Science Form One to Four Draft Syllabus and Guide and

accompanying Trial Guidelines, the N.Z. School Certificate Science Prescription and the N.Z. Form 5 Modular Science Trial Guidelines.

It is noteworthy that the topic Energy is one of only four content areas in the primary syllabus (the others being Living Things, Matter and Time and Space). In this Energy section a number of conceptually difficult and abstract ideas are stated leading to the principle of conservation of energy. In considering this mammoth task expected of teachers and of pupils aged from 5 to 10 years old it is worth recalling the analysis in LISP (Primary) of teacher opinions about teaching science at all (Osborne and Biddulph 1985, p.14):-

'Constrained by their view of students, their view of learning, their expectations of pupils, and the image they have of their role in the classroom, they can feel trapped in a situation where they see no solution, except to avoid science as much as possible. Over 50% of the teachers interviewed spontaneously mentioned the widespread lack of confidence by teachers about teaching science'.

Our interviews with the primary science advisers (SA) who have an overview suggest that the energy topic is the least preferred of all the content areas because it is perceived to be undefinable:

'And so if you are looking at it from that point of view, the teachers are saying I'm not going to take energy because I don't now what it is. But then that could be a legitimate excuse for not taking it because, um to my way of thinking in any case it'd be the most abstract we've got in the environment'. (T62, SA p9)

Or because teachers see it as frightening:

'A lot of them are quite, you know, they are scared of that, [energy] because they don't think they know enough about it and most of, well I might be wrong here, but I think a lot of ladies and I think, a lot of people tend to immediately have connotations of 240 volt power, when you're talking about electricity. 240 volts is dangerous and so they initially stay clear of it'. (T48, SA, p3).

We found that, in general, those primary teachers who do teach science, if they tackle the energy topic, tend to avoid using the word energy and rather to provide their students with experience of mirrors, magnets, cells, light bulbs etc.

The secondary school treatment of energy is more elaborated and is taught by teachers with more science training. Teachers nevertheless still express concerns.

'I hate energy topics. Ah I say, I say that with great vehemence. You're dealing with something which is an abstraction. You can't put concrete, concrete items in front of them and say "that's it" ... I'm, I'm telling you that it's with some trepidation tht I start each year and I sigh deeply. And really I'm teaching it because I have to - it's in the syllabus." (T22, Px, 30).

A section of the Science Form One to Four Draft Syllabus and the Objectives from its accompanying Trial Guideline (Appendix A) indicates the detail expected and even deemed achievable by 80% or more of the students (Preface).

An analysis of this section by intensive classroom observation is a major feature of LISP (Energy) and is what we refer to as Phase 2.

PHASE 2 : RESEARCH DESIGN

Phase 2 began in February, 1986. We sought a biology teacher, a chemistry teacher and a physics teacher in three different schools (rural/urban, coed/single sex, state/independent) who would be teaching this section during the first half of 1986. Teachers were selected from as wide a cross-section as could be found given the constraints of distance, time and pressures on already overworked teachers. Data are gathered in a very detailed manner as outlined below (the procedure is an adaptation of that used by Bell (1985)).

- (a) audiotaping each lesson
- (b) autiotaping interviews with the teacher
- (c) autiotaping students interactions during lessons
- (d) audiotaping a few selected students outside of lessons
- (e) obtaining the teachers' scheme of work for the topic
- (f) asking the teacher to keep a diary
- (g) copying all worksheets etc handed out
- (h) photocopying (with consent) students' work
- (i) carrying out pre and post surveys
- (j) obtaining the teacher's assessment test and the student's answers
- (k) making field notes on the lesson.

Research questions which are directing the data collection and analysis are:

- (a) What are the teachers' constructions of the concept energy, and of the requirements of the syllabus section on Energy?
- (b) What teaching activities and learning opportunities does the teacher provide.
- (c) What are the meanings constructed by the students of the classroom events?
- (d) What evidence is there of students using alternative frameworks an school science ideas?
- (e) Do the students' concepts change as a result of the lesson?

To date two of the three observations have been completed. Mary, a biology/chemistry teacher by qualification and training is in her fourth year of teaching and teaches at School A, a state coed, rural school (roll = 1200). Jack, who teaches in School B (state, coed, rural, roll = 600), qualified and trained to teach physics 16 years ago.

The two classes observed were of above average ability in the School's opinion.

The researcher noted a positive interaction between each teacher and the students. Both are well regarded by their colleagues and are known to be amongst the most competent of science teachers.

PHASE 2 : PRELIMINARY FINDINGS

With a great deal of data still to be transcribed and analysed only preliminary findings can be reported. It may help to note some shift of emphasis to some extent. Previous LISP research has concentrated on the existing frameworks students bring to science lessons. Little investigation has been undertaken into the frameworks which teachers bring to science lessons. We wished to explore these and to investigate how they might affect students' learning. In the context of Energy our interviews had suggested (and a preliminary SERU Brainstorming Conference has strongly proposed) that teachers from differing disciplines hold differing concepts of energy.

The two teachers involved in Phase 2 expressed the concept of energy that they intended to 'get across' to their class.

"I'd hope that they can look at the world around them and see the energy flow through it." (T101, Mary, School A)

Mary's definition is widely held by biology teachers and some chemistry teachers interviewed in Phase 1.

"I tend to take it from the point that energy is something that begins with the sun and is converted by living things and it's passed along living things and they utilize that energy." (T53, Bio)

"... just that, you know there is such a thing as energy. Right. And you can't lose it and you can't, you know create any more just innormal situations. And I suppose I just imagine it as something that, that's there. And it comes from the sun to the earth..." (T23, Ch)

Jack's definition below is widely held by New Zealand physics teachers and by some chemistry teachers interviewed in Phase 1.

"...If they have some sort of operational definition, something they can, shall we say in terms of something happening. ...Unless there's some sort of idea of it actually doing something it rarely has much meaning. So I'm going to be trying to emphasize this idea that energy really is the thing that gets a job done." (T150, Jack, School B)

"Well we start off with a rather simple definition... Ah well I keep it to simple terms. Energy makes things happen or energy can be stored ... It's something happening then if, its a sort of working form and if you can't see energy there, then that it's stored and although it's a rather, you know, you can't explain everything it's helping them you know, a way of reminding them." (T55, Px)

"And one boy came to me and he said "Define energy." And I said "Oh it's the ability to do work." "Define work." "You know, oh, it's the transfer of energy from one form to another like you lifing an object and things like that." (T44, Ch)

These statements suggest two alternative frameworks close to Warren's (1982) materialist or substantial approach (apparently important to biology teachers) and Duit's (1985) ability to do work and cause change (apparently important to physics teachers). Other frameworks may well exist as the following statements imply.

"It's extremely abstract - it's a beautiful unifying idea." (T42, Px, 30, HOD, SM)

"I remember once saying to a physics teacher years ago that it was the driving force of life or something and he went through the ceiling." (T51, Ch, 10, HOD)

"Energy is god. Um in so far as you are. It's the ultimate. What the universe is about. What all living things are about and no matter what aspect of intellectual endeavour you study you eventually get back to life force which is energy. Ahh. Whether you're talking about religion or art, politics or science and ahh if you can asw... I suppose energy is the modern version of the philosopher's stone. That, if you can find out and unlock the key to energy you have the power of the knowledge of the universe at your disposal." (T36, Ch, 23, HOD, SM)

There are already clear suggestions of very different frameworks with links, (not always strong), to the discipline of academic training.

We next explore whether these different frameworks result in different classroom experiences for the students. For Jack, School B.

"What I'm trying to do is set up a large number of experiments and they'll be working themselves through that for a while and then we'll be analysing the things that went on in them and then trying to extract the ideas out of those experiments." (T150)

Jack's students carried out a number of Energy circus experiments as in ASEP's 'Energy in Change'. One involved heating a digital thermocouple with a match. (Station 3 in the conversation below). The students were asked to 'complete the energy flow diagram as one energy goes from one form to another' (from worksheet for Station 3).

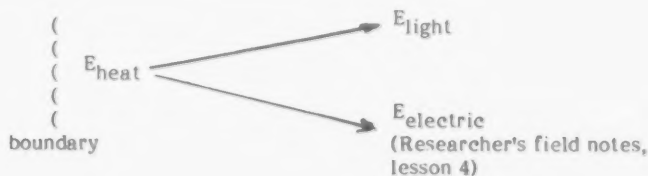
'J "Station 3, Who would like to tell us what they wrote down for Station 3?"

A number of different forms were proposed.

'P "Kinetic."

J "Right, can we again just say, otherwise we're to end up in a bit of confusion about where to start here. We'll start with the idea that the match is already lit because that's strictly right. So where would it be after you've lit the match? From the lit match where would you go?" (T162, p4,5)

Jack set firm boundaries in the discussion of each experiment. On the blackboard he reinforced this in the energy flow diagram. He wrote:

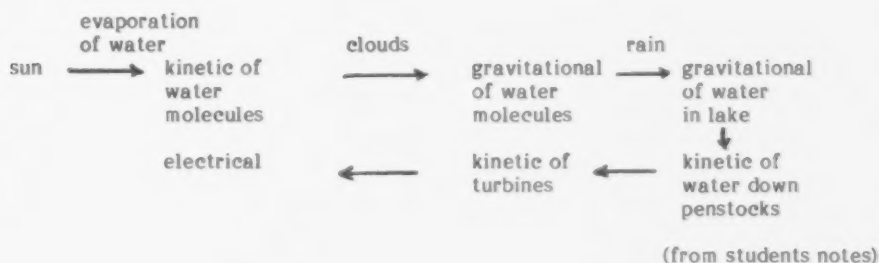


But Mary had energy flows going back to the sun. One of her students recounted his analysis of the same experiment where the thermocouple was heated by a bunsen burner thus:

"The sun gives energy to plants in photosynthesis. Plants die down eventually (and) you've got gas, natural gas and it's refined and delivered to here. The gas comes and you lit it. It reacts with oxygen and burns and then you get heat energy and produces

a more flow of electrons in one wire than in the other. So you've got sort of like two, can you call that positive and they go through and they form. The movement of electrons they form electrical energy then because of needles in galvanometers that produces kinetic energy." (T125, p2)

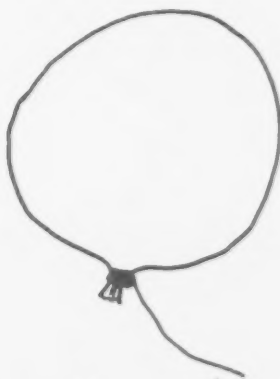
There are no boundary conditions laid down in Mary's lessons. Analysis of all systems originated at the sun, for example, a hydroelectric power station.



Framing or creating a boundary to a system being considered results in a very different learning experience from considering all systems going back to the sun.

Jack emphasized closed systems in a state of change and avoided referring to energy in static systems, a view of energy that is strongly implied by the Trial Guidelines for the teacher. Mary however set the following question in a test:

'Identify the main form of energy shown in the following diagram



The answer required by Mary was gravitational. The answers given by the students were kinetic, strain, chemical, potential kinetic, no answer, gravitational, potential. Discussion revealed their disagreement that there was a single right answer to this question.

Mary had considerable disquiet about teaching this topic before she started.

"It's easier almost to have it as a part of different topics. You can talk about energy. Than as a topic on its own because it's a hard concept to explain and it's a hard concept I find to get across to kids. Um. As for my views of it in the curriculum I guess perhaps because I'm not a physicist and so I've never studied energy as such I've found it as a something you just look at in biology when you're looking at energy flow through your systems so obviously it's important." (T101, Mary, School A)

This section of the syllabus contains very little about energy in biological systems, so that biology orientated teachers like Mary have little support for their framework of energy on. Her diary was peppered with "find a second experiment that works," "attempt less in the period", "find the panadeine before the class begins," "get started faster," "explain in more detail," "explain equipment thoroughly." "Scrap *." "Scrap it." A preliminary conclusion could be that when the curriculum matches badly with her framework frustration results.

Can the reverse happen when physics teachers confront energy in biological system? This is a comment from a physics teacher of 30 years teaching experience.

"I know there's great confusion when I teach, when I used to, well I still do from time to time, teach food chains and stuff like that. And whether we're talking about energy flow through it or whether we're talking about food which might be the, the chemical part of it - the materials passing through the system. Or whether we're talking about just dependence of one thing or another - Oh - just what these various networks mean. There's great confusion in there. Don't know if I do much better with it myself." (T22,p1)

CONCLUSION

In concluding this tentative account of our research we can note that the research questions about teachers' alternative frameworks and their interaction with the curriculum and with classroom learning by students appear to be extremely important questions for researchers in the area of energy teaching and learning and presumably in wider contexts.

There are also implications for science teacher education, both preservice and inservice. It is clearly necessary to address the confusion in both teachers' and students' understandings of energy.

We would like to thank Mary and Jack, their Principals, and classes for allowing us to observe their teaching and learning, SERU colleagues for their sustained support and in particular Mark Cosgrove for his editing of this paper's drafts.

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APPENDIX

N.Z. Science Forms One to Four Draft Syllabus and Guide (Level 5) Department of Education, Wellington, N.Z. 1978.

SECTION 3

ENERGY

AIM: To develop further the simple ideas of energy gained in level 4, and introduce some important units of energy.

After completing this section, a student should be able to:

- Content
- 1 a Classify the different forms of energy as radiant, heat, electrical, sound, chemical, kinetic, potential:
 - b further classify potential energy as: chemical, gravitational or elastic:
 - c identify transformations of energy when they occur and state the forms involved:
 - d accept that in any transformation energy is conserved:
 - e classify resources of energy as renewable or non-renewable:
 - f trace an energy form back to the energy resource:
 - g state the following relationship for an object being lifted or dropped:

$$\begin{array}{ccccc} \text{Change in energy} & = & \text{distance} & \times & \text{gravitational} \\ \text{of object} & & \text{moved} & & \text{force on object} \end{array}$$
 - h give an operational definition of one joule of energy:
 - i use the units joule and kilojoule, and their symbols, correctly.
 - Skills
 - 2 a Draw cross-sectional diagrams of scientific apparatus using pencil and ruler:
 - b assemble individual items of apparatus for a particular purpose:
 - c use the equation given in 1g to calculate the change in potential energy when an object is lifted or dropped, and record the mathematics of this calculation.
 - Attitudes
 - 3 a Recognise the need to use energy resources wisely:
 - b critically examine news reports that poorly managed energy resources are producing health, environmental or economic problems.

Science Forms 3 and 4 Trial Guidelines, Forms 1 - 4 Draft Science Syllabus (Level 5)

SECTION 3

ENERGY

OBJECTIVES

After completing this section, pupils should be able to:

- 1 a Recognise the existence of energy in their surroundings.
- b Classify energy forms as heat, sound, radiant, electrical, movement (kinetic), stored (potential), chemical, nuclear.
- c Analyse an experiment or practical situation involving up to four energy changes.
- d State in the form of simple word equations the energy forms involved in an energy change.
- e Identify all forms of energy produced in a change that produces two or more types of energy.

- f Know that some energy is lost in all practical energy changes.
- g Know that in most energy changes, energy is conserved if heat losses are included.
- h Trace energy changes back to their source.
- i Know that food provides the energy for living.
- j Identify the main energy sources available to man.
- k Identify the sources of energy which may soon be in short supply.
- l Recognise a need for conservation of resources.
- m Evaluate qualitatively the effect of the height and weight of an object on its total stored energy.

EXTENSION OBJECTIVES

Average and above average pupils should also be able to:

- n Identify potential energy as being either elastic, gravitational or chemical.
- o Locate information from references.
- p Produce a report on their investigations.
- q Use the following relation for stored (potential) energy

$$\text{stored energy} = \frac{\text{height}}{\text{raised}} \times \frac{\text{gravitational}}{\text{force on object}}$$
- r Give an operational definition of one joule of energy.
- s Use the units, joules and kilojoules to measure energy used to lift objects and to measure food energy values.

Research In Science Education, 1986, 16, 184-190.

MOVING FROM ONE SETTING TO ANOTHER: STUDENT REACTIONS AROUND TRANSITIONS

Warren Beasley and Jim Butler

INTRODUCTION

This study focuses on the off-task behaviour patterns of students before, during and after a teacher initiated transition from one classroom setting to another. In an earlier study of transitions in science classrooms (Butler and Beasley, 1985), the overall level of student off-task behaviour decreased during the transition phase. This decrease in off-task behaviour was explained in terms of a student perspective which would regard transitions as a period of relief from cognitive and physical strain, and greater co-operation in the expected behaviours would be anticipated.

That study also presented results which showed that the better managers of classrooms are the better managers of transitions which cause no significant change in the off-task behaviours and fit into the flow of the classroom. In the case of the below average manager, the transition does cause a significant decrease in off-task behaviour and can probably be interpreted as the students in these classrooms experiencing much greater relief from the fairly disorganised settings on either side.

This study makes a more fine grained analysis of the individual student reactions around transitions. The main questions are: Do individual students maintain a consistent behaviour pattern around transitions? Are these behaviour patterns related to the level of management expertise demonstrated by their science teachers? Does a rapid increase of off-task behaviour trigger a transition to a new setting?

THEORETICAL FRAMEWORK FOR STUDENT CO-OPERATION

It will be assumed with Westbury (1978) that the classroom appoints four goals for the teacher:

- (1) Coverage of the syllabus objectives.
- (2) Mastery by students of those objectives.

- (3) Affect on the part of students towards the subject.
- (4) Attention that students give to the classroom activities and tasks (Doyle, 1979).

These goals create a four ball juggling act for the teacher because exclusive concentration on any one is sure to jeopardise success at achieving the others. It is impossible to disentangle the four goals but in this study, the latter two are considered more relevant. There may be some tension between affect and attention in certain situations. For example, beginning teachers are often given advice by their peers not to smile in class until three months into the school year. Affect must be sacrificed on the altar of attention, but it can be otherwise.

Doyle (1979) subsumes these two goals stressing attention more than affect under the topic of co-operation, and sees the fundamental goal of a teacher as gaining and maintaining co-operation in classroom activities. Co-operation is a necessary but not sufficient condition for learning. What Doyle argues is that the implicit theories of teachers are primarily theories of co-operation - how to optimise and maintain it, rather than theories of learning. Practising teachers tend to assess the worth of an activity, and when and how to make the transition to a new topic of activity on the basis of student reaction and involvement rather than on achievement. And even though Doyle does not directly state the reason, it is clear that affect and attention are much more apparent in the classroom than is achievement. Teachers, according to Doyle allocate time to activities in a manner that maximises student co-operation.

The observational implications of Doyle's position are as follows:

- (1) teachers will plan their lessons so that the activities they include and the time they devote to these activities as determined by the transitions they plan, will maximise co-operation.
- (2) teachers will make transitions to new activities in order to reduce an unacceptable level of off-task behaviour.
- (3) teachers will continue an activity for a time that is well beyond the time of mastery for most if the level of co-operation is high.

METHODOLOGY

The intention of the project was to observe naturalistically the off-task behaviour patterns of students in science classrooms. The subjects for the study were the teachers and pupils in 24 junior science classrooms in six metropolitan schools. The details of the methodology are provided in an earlier study (Butler and Beasley, 1985). In essence, simultaneous video records of teacher and students were obtained of complete lessons.

The ninety-one lessons obtained were divided into the three lesson settings of Whole

Class Activity (WCA), Small Group Activity (SGA) and Individual Activity (A) (Butler, 1980). The transitions chosen for this study were those which separated lesson settings which existed for a period of at least 5 minutes. Six students were selected for continuous observations from the videotape of each lesson (Butler and Beasley, 1985).

The crucial feature of the methodology that needs to be discussed is the coding of off-task behaviour (Butler et al, 1980). The student behaviours were coded as off-task if they were outside the implicit or explicit behavioural expectations of the teacher. These expectations changed significantly from one setting to another and in the transition periods between settings. The on-task and off-task sets of student behaviours were defined for each type of setting and for each type of transition. Some behaviours - like throwing objects - are always in the off-task set; but some others - like students talk - can transfer between the two sets depending on the setting, or type of transition.

The off-task sets in each of the three settings generally overlap but do have unique features. For example, animated 'student-student' talk is off-task in WCA and IA, but not in SGA where it is essential to the setting. In relation to coding, the WCA and IA settings generally show up off-task behaviours more starkly than SGA where it is more difficult to decide.

RESULTS

The thirty-two lessons (with 46 transitions) accepted in this study were taught by 15 teachers and contain four types of transitions within two major lesson patterns.

- | | |
|-------------------------|-----------------|
| (1) Explanatory Lesson: | WCA - IA - WCA |
| (2) Practical Lesson: | WCA - SGA - WCA |

The encoded data represented the level of task involvement of each student for each ten second period of the completed lesson. Four distinct phases of time surrounding the transition period were identified from the lesson sequence. These phases are represented in Figure 1 and are labelled as: Whole Setting prior to Transition; Two Minute Segment prior to Transition; The Transition; Two Minute Segment after Transition; Whole Setting after Transition.

For the 179 students coded, the mean off-task behaviour levels in each phase are presented in Figure 2. Correlation coefficients of student off-task behaviour across the five periods of time described above are presented in Figure 3.

Similar data is segmented into two groups. Those students of the above-average managers (Butler and Beasley, 1985), and those of students of below-average managers. Figures 4 and 5 represent the correlation coefficients of student off-task behaviour across the five phases for these two classifications of teacher management effectiveness.

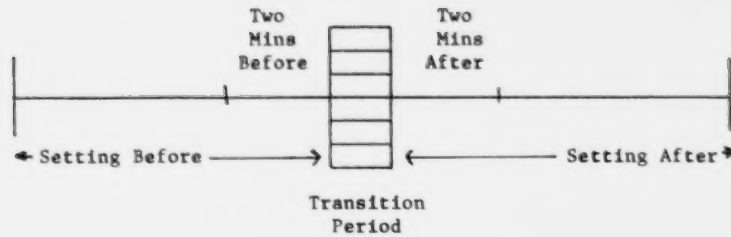


Figure 1: Phases of Lesson Sequence around Transitions

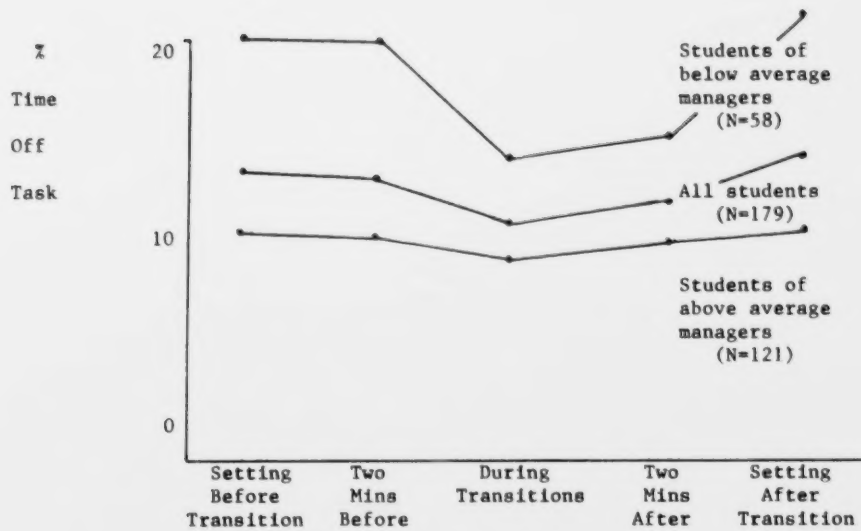


Figure 2: Effect of transitions on student task involvement.

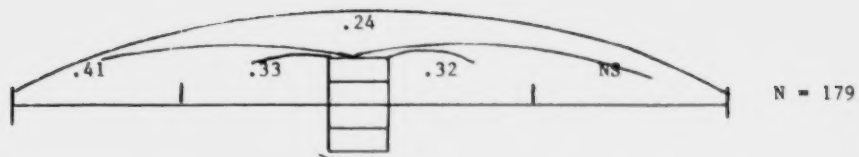


Figure 3: Correlations of Student Off-task behaviour across transitions for all Students.

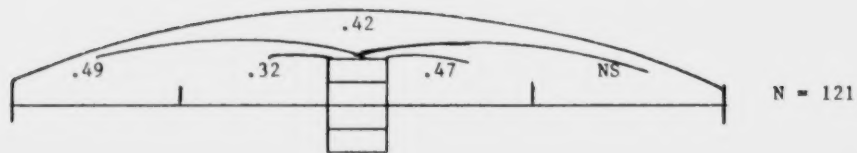


Figure 4: Correlations of student off-task behaviour across Transitions for students of above average managers.

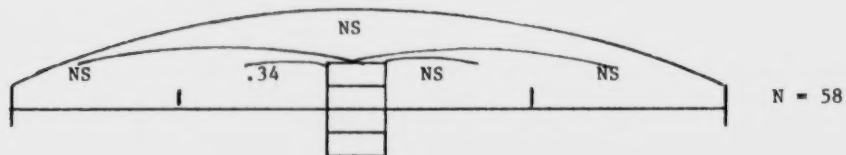


Figure 4: Correlations of student off-task behaviour across Transitions for students of below average managers.

DISCUSSION

The results represented in Figure 2 do show that for below average managers the transitional phase provides a period of increased attention to the task by students. This attention does continue with the new setting for at least two minutes. However the off-task behaviour increases rapidly soon after. For above average managers the low level of off-task behaviour is consistent across all phases of the lesson. For the below average managers, the results are generally consistent with one of the implications of Doyle's (1979) co-operation model of classroom management. Transitions to new activities do reduce unacceptably high levels of off-task behaviour. However after a few minutes, any gain is soon dissipated.

The actual timing of the transition does not seem to be related to the class level of off-task behaviour. The prediction would be for higher levels of off-task behaviour just prior to a teacher initiated transition to trigger a transition. However, the mean off-task levels for the whole setting prior to a transition and for two minutes just prior to a transition remain fairly constant for all teachers. The reasons for transition to another segment do not appear to be related to rising levels of off-task behaviour. It may be more related to coverage of syllabus objectives (Westbury, 1978).

Some insight into the reaction to transitions of individual students is given by the correlation coefficients presented in Figures 3 to 5. Taken collectively, the correlation coefficients reported for all students (Figure 3) appear to be accounted for by the students of the above-average managers (Figure 4) with the exception of the two minute period just prior to the transition and the transition phase. For both classifications of managerial effectiveness, the correlation coefficient for student off-taskness just prior to transition and during the transition phase is constant and is of the order of .33.

In interpreting the magnitude of the correlation coefficients, the effect of the transition in reducing the overall level of off-task behaviour must be kept in mind. It does encourage more on-task behaviour. For some students, the off-task behaviour becomes on-task, without a corresponding number going off-task. Therefore, it is predictable that correlations of student behaviour patterns around transitions cannot approach one.

For students of above-average managers (Figure 4), the pattern shows some consistency. It is apparent that students who are off-task during the setting prior to the transition are more likely to be off-task during the consequent phases of the lesson. Above-average managers keep most of the students on-task for the whole lesson. One hypothesis would be that a small core of students continue off-task for most of the lesson and are generally unaffected by a transition or a new setting. This group either remains undetected by their teacher or are ignored as the overall level of off-task behaviour is acceptably low.

For below average managers, the effect of transitions on individual students is much more random (Figure 5). The lack of stability appears to indicate that students are engaged in random off-task behaviour. It was only the period just prior to the transition and the transition itself that a degree of stability of students who are off-task was observed.

Transitions are challenging phenomena to understand. This study has suggested a more predictable pattern of student off-task behaviour is possible for above-average managers. Although different settings do attract different levels of off-task behaviour of students (Butler et al. 1980), it appears that it is the overall management expertise of teachers across the whole lesson which is related to the attention of students. The timing of a transition does not seem to be related to the level of student off-task behaviour just prior to the transition. For science teachers in this study, it could be postulated that coverage of course content might be a more important determinant.

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USING COMPUTER SIMULATIONS TO PROMOTE ACHIEVEMENT AND TRANSFER

Ronald Oliver and James Okey

Computer simulations have played an increasing role in computer-assisted instruction (CAI) in recent years. Early CAI was devoted primarily to drill and practice but the increased capability of school computers has been accompanied by more attention to higher level objectives toward which most simulations are directed.

The role that simulations of all kinds have in instruction is to present some simplified model of reality that can be observed and altered. The simulation provides a means of experimenting with the world. Computer simulations are especially important because they allow interaction with difficult, dangerous, expensive, or time-consuming events. A student with a computer simulation can, for example, try wide ranging temperatures to determine their effect on reactions or determine successive generations of fruit flies in a matter of minutes.

In addition to the pedagogic value of computer simulations (i.e., compressing time, reducing dangers, etc.), they promise some significant advantages in learning as well. Because computer simulations allow students to make choices and observe and act on consequences, they provide a way to study cause and effect relationships, to make predictions, to test hypotheses, to gather data, and to draw conclusions. It is these outcomes that constitute higher level thinking and problem solving that are frequently mentioned among the important objectives of schools but not so frequently found in the daily activities of classrooms.

Publishers, through the materials that accompany computer simulations, are not timid in setting forth the high level objectives to which their simulations apply. For example, one publisher of a simulation aimed at upper primary level students claims that use of the simulation will increase reading comprehension, enhance communication, promote co-operative behaviour, and provide problem solving experience. A problem with computer simulations such as this is not that the objectives are outlandish or that claims are distorted or excessive. Rather the problem is one of face validity - what students do while using the simulation doesn't involve obvious school tasks and thus the link between

using the simulation and achieving the high level objectives is not clear. In this particular simulation, students attempt to assemble a small raft on the screen so they can escape drowning in an impending flood.

Because simulation tasks such as building rafts or managing buffalo herds are not obvious school tasks, the value of the simulation must be sought in what it helps students learn beyond the simulation itself. Thus the simulation skills themselves are not as important as showing that they can be applied or transferred to other tasks of more obvious value. The computer simulation becomes important not for what students do while using it but rather what other things they can now do because of some generalizable skills they have acquired.

Two major questions therefore arise when evaluating computer simulations that provide somewhat fanciful tasks for students.

1. Can students successfully engage in the simulation tasks?
2. Can the simulation skills be transferred or applied in other situations?

PURPOSE OF THE STUDY

The purpose of this study was twofold. First, means of acquiring skills using a computer simulation were studied. The study alternatives were each examples of ways that schools presently organize computer study. Secondly, the purpose was to see if the skills acquired when using the computer simulation could be applied in other settings. In other words, the second purpose looked at the transferability of the skills to new, non-computer problems.

PROCEDURES

Sixth grade students ($n=50$) in three different schools used computer simulation in three different ways. In the first school the students worked in pairs each sitting in front of the terminal and alternatively taking turns in responding to the simulation tasks. At the second school students worked in groups of four. Although a bit more crowded, they too all sat in front of the terminal and entered responses to the simulation events. Students in the third school were directed as pairs to work at the computer terminal as space and time permitted. In this instance only a single computer was used over a number of school days so that all students had an opportunity to interact with the computer simulation. In the first two schools, the students were taken to a computing laboratory on a nearby campus where all students in the class simultaneously worked on the simulation either in pairs or groups of four.

The simulation used, called *Raft Away River* (Jacaranda Wiley, 1984), places students in a river valley following an accident on a rafting trip. The accident leaves them stranded with no way to safety unless they can build another raft from available

trees. During the process of building the raft they must feed themselves by catching and cooking fish or eating berries. Periodic rains and bad food occasionally cause illness and suspend work on the raft. Because each participant has specific tools (an axe, rope, fishing line, or matches) they must cooperate in the cooking, eating, tree cutting, and raft building. According to the literature provided with the computer program, it provides students "an opportunity to develop skills in reading comprehension, communication, cooperative behaviour, and problem solving."

Students in the three groups worked with the computer simulation over a period of six weeks. The two groups that used the computers in the laboratory setting were each scheduled for five sessions lasting 45 minutes to an hour. Approximately 20 minutes was required at the first session to explain procedures and orient them to the computers but after this all time was devoted to interactions with the simulation. Computer use by the third group of students was considerably less systematic. A single computer was available in the classroom for one half day each week. During this half day the teacher directed pairs of students to use the computer. The sessions for these students were shorter (usually about 15 minutes) and were less frequent (2 to 4 sessions for each student compared to 5 for the other groups). In terms of total time for computing, students in this latter group had approximately 25 to 30 percent as much time working with the simulation as students in the other two groups.

The total time for using the simulation was the same for each of the two groups using the computer laboratory (five sessions of 45 to 60 minutes). However, there were differences in use because of participating as a member of a pair or a foursome. Each group would make essentially the same number of responses but the individuals in a pair would have twice as many individual choices to make. Students in pairs and foursomes also take on somewhat different roles because tasks can be more differentiated within a larger group. For example, in a foursome one person can cut wood, another can carry it to the raft building site or fire, another can be catching fish, and still another can be building the raft. In a group of two each individual must take responsibility for more than one of these chores.

Four measures were completed by each student - one prior to the computer work and three afterward. The prior measure was a test to determine the logical thinking ability of students. The three measures following use of the simulation measured attitudes toward computing, knowledge of the procedures and skills involved in using the simulation, and ability to transfer simulation skills to new topics. Each of these measures is described more completely below and in Table 1.

Group Assessment of Logical Thinking (GALT).

This 10-item multiple choice test requires double responses to each item - one requesting an answer and the second a justification for it. The ten items are used to assess five kinds of reasoning ability - correlational, probabalistic, conservation,

combinatoria, and proportional. This test has been shown to be both a valid and reliable measure of logical thinking ability (Radrangka, Yeany & Padilla, 1983). Logical thinking was thought to be a prerequisite for successfully completing the computer simulation in this study.

TABLE 1
INSTRUMENT DATA

Measure	Type	Number of Items	Possible Score Range	Mean Score	Standard Errors	Test Relia- bility
Group assess- ment of Logical Thinking	Multiple Choice and Completion	10	0-10	3.2	.24	.62
Attitudes Toward Computing	Likert Scale	24	24-96	80.0	1.1	.78
Raft Away River	Multiple Choice, Completion, and Problem Solving	17	0-20	12.9	.49	.71
Transfer of Learning	Problem Solving	10	0-18	8.0	.53	.73

Attitudes Towards Computing (ATC)

This is a 24-item Likert scale in which students are given statements (e.g. I find computers difficult to use or Computers help you to learn) and asked to rate them as Strongly Agree, Agree, Disagree, or Strongly Disagree. Items on the scale are designed to assess three dimensions of attitude in using computers to learn, and the value of computers as aids to learning.

Raft Away River (RAR)

This 17-item test consisted of a combination of multiple-choice, completion, and problem solving items. The items determined whether students had the knowledge needed to participate in the simulation successfully. The test also determined whether paper and pencil problems like those posed in the simulation could be completed.

Transfer learning (TOL)

In this 10-item test problems were given to students that required skills similar to those involved in the simulation. One problem required the sequencing of 6 events in a logical order. Another involved moving furniture in a room in a systematic way to effect

a new arrangement. Five of the problems provided a grid system to students and required them to either execute or design steps to move an object about on the grid. Three of the problems presented a picture of a game board on which students were asked to plan moves to gain high scores. The emphasis in these problems was on sequencing tasks to solve a problem. In some respects the paper and pencil transfer problems were more difficult than the computer simulation tasks because they did not show results after each step in the problem. The student was required to envision the results of a series of steps or possibly make some kind of drawing to show intermediate steps.

Tape recordings were made of selected student groups working with the computer simulation in the computer laboratory. The purpose of these was to examine the tactics and strategies students adopted and to determine how much conflict or cooperation occurred in the groups. Individual interviews were also held with 6 students and tape recorded. The interviews focused on understandings of the various tests the students completed as well as their understandings of the simulation itself.

RESULTS

Descriptive statistics on all measures for the combined group and the three individual schools are given in Table 2.

Students working in pairs at the computers in School A had the most favourable attitudes toward computing and the highest scores indicating the most knowledge of the simulation (RAR quiz), but they still had the lowest scores on the transfer (TOL) measure. Their logical thinking (GALT) scores were also lowest.

Students in School C that used the computer simulation the least had the least favourable attitudes and knew the least about the simulation itself (RAR quiz) but still scored highest on the transfer (TOL) measure. These students also had the highest logical thinking scores of all students. Students from School B who worked in groups of four had the intermediate scores on all measures.

Because the students differed in their logical thinking ability, a capability considered important in successfully doing the simulation task, it was used as a covariate in an analysis of the several outcomes used in the study. The results of this analysis are shown in Table 2. Significant differences were found in attitudes toward computing and knowledge of the simulation itself. In each case the two groups of students working with the laboratory computers significantly outscored the third group that used the computer less and on an occasional basis. But the transfer of learning (TOL) scores show no significant differences even though School C scores are substantially higher. Logical thinking ability correlates strongly with transfer ability ($r=.71$) and the raw scores were adjusted to bring these mean transfer scores closer together in the analysis of covariance.

TABLE 2
DESCRIPTIVE STATISTICS FOR ALL MEASURES

	Overall n=50	Max Score	School A (Lab pairs) n=15	School B (Lab quartets) n=15	School C (Single Computer pairs) n=20	School Differen- ces **
Logical Thinking	3.24* (1.7)	10	2.7 (1.6)	3.1 (2.0)	3.8 (1.5)	F=
Attitudes Toward Computing	80.0 (7.5)	96	82.8 (4.9)	82.7 (6.6)	75.9 (8.2)	F=7.79 p=.001 <u>A B C</u>
Raft Away River Quiz	12.9 (3.5)	20	14.5 (4.0)	13.7 (2.7)	11.2 (2.9)	F=7.44 p=.002 <u>A B C</u>
Transfer of Learning	8.0 (3.7)	18	6.4 (3.9)	8.0 (3.1)	9.2 (3.7)	F=1.19 p=.31 <u>C B A</u>

* Each pair of values shows the mean score for the measure and the standard deviation of the scores in parentheses.

** Analysis of covariance results. Logical thinking ability is the covariate. Adjusted mean scores for the 3 schools are shown from left to right (highest to lowest) by the letters A, B, and C. Letters underlined by the same line are not significantly different from one another.

Analysis of the tape recordings revealed a variety of behaviours associated with group work and strategies in carrying out the simulations.

- * anticipating events or consequences "I'd better go get some fish before the fire goes out."
- * planning several moves ahead "...then I'll wait for you to bring the wood up and I'll build the raft."
- * scenario of moves "...then we'll cut wood ... and catch some fish ... and build the raft ..."
- * cooperative planning A: "Now you just keep cutting wood."
B: "OK"
C: "And I've got to go to the tree."
D: "And I've got to go to the island."

Over the several class periods that students worked with the simulation it appeared that cooperative behaviour increased. At the outset, students were more concerned with

their own turn than how their actions affected accomplishing the task. There were even instances of outright resistance to cooperation. One student, for example, wasn't going to share any of the fish he had caught with others. As time went on students seemed to cooperate more readily as it became clear that differentiation of roles and sharing of work was essential to accomplishing the task.

One observation of students that stands out during the simulation was that they were always on task - sometimes boisterously, occasionally argumentatively, and usually excitedly, but always on task. Interest never flagged. Certainly there was novelty in use of the computer although these students all had some prior experience with computers in their schools. But the interactive, problem-orientated nature of the task completely captured their attention. This occurred even though conditions in some cases seemed less than ideal with 2 or 4 students competing for space in front of a single computer.

CONCLUSION

As students used the computer simulation more they clearly acquired more of the knowledge needed and appeared to be able to solve paper and pencil problems like those found in the simulation. Attitudes toward computing were also a bit more favourable for students using the computer simulation the most. But these program gains did not translate into greater ability to transfer skills to new, non-computer tasks. Students in the group with the least knowledge concerning the simulation scored the highest on the transfer test.

No formal measures of cooperative behaviour were used - only informal observations of students as they worked together. It appeared that some of the initial individuality and authoritarianism gave way to more cooperative behaviour as students realized how success depended on working together.

To return to the point made early in this paper - a simulation such as Raft Away River has little obvious value in and of itself. Schools would seem to not be interested in whether youngsters can assemble small brown logs on a screen in the shape of a raft. This is not a skill with any inherent value. But schools are concerned with effective outcomes such as cooperative behaviour and with cognitive outcomes such as sequencing ability and problem solving. To the degree that the Raft Away River simulation promotes these outcomes, it has value.

Although transfer of learning appeared not to be strong in this study and not differentially effective based on skill with the simulation, it shouldn't be concluded that the computer program failed. First, the contact with the program was for only a few hours so a modest amount of learning is all that can be expected. Problem solving ability

is a long term goal of schools contributed to by various subject areas over several years of study. One short learning stint as in this study would be expected to influence problem solving in only a small way. Secondly, measuring the ability to transfer or apply skills in a new area is difficult because it is easy to misgauge transfer tasks. If the transfer is too remote from the learning task, students are unable to see common elements in problems and apply appropriate skills. If problems are set too close or similar to those in the learning task, students don't have to comprehend a new setting and apply old skills to it.

Studies should be continued that seek evidence about the claims made for computer learning programs. Reviews of computer programs by educators provide important points of view about accuracy, completeness, and purpose. But they fail to give assurance of whether using the computer software actually promotes the behaviours or objectives specified by the developers. Such information would be valuable for all kinds of learning materials but it is especially important for school activities that do not obviously promote academic tasks.

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Research In Science Education, 1986, 16, 199-207.

EVALUATING STUDENTS' MISCONCEPTIONS BY MEANS OF DIAGNOSTIC MULTIPLE CHOICE ITEMS

David Treagust

INTRODUCTION

In most misconceptions research, the usual means for obtaining information about students' misconceptions has been through individual student interviews and/or open-ended response questions on specific science topics. Osborne and Gilbert (1980) and Watts (1981) have described a variety of interview formats or procedures for conducting these interviews. The two most commonly used procedures by researchers are interviews - about - instances and interviews - about - events. Some researchers such as Mitchell and Gunstone (1984) have used an interview format which is a mixture of these procedures.

Exceptions to this line of research have been multiple choice tests described by several authors such as Tamir (1971), Linke and Venz (1978, 1979), Helm (1980), Trembath (1984) and more recently by Halloun and Hestenes (1985). The multiple choice tests by Helm (1980) covered a semester's work in college physics while that of Trembath (1984) covered a wide range of subject content areas in a variety of disciplines at the college level. Only in the case of Tamir (1971) and Linke and Venz (1978, 1979) and Halloun and Hestenes (1985) were the tests related to any specified and limited content structure.

The work by Tamir (1971) on an alternative approach to construction of multiple choice test items was innovative in that the distractors for the multiple choice items were based on students' answers to essay questions and other open-ended questions and addressed underlying conceptual knowledge related to a limited content area. As Tamir (1971, p.306) states "these alternative [responses] being representative of typical conceptions and misconceptions of students have a distinctive advantage as compared to regular test items for which professional test writers provide the alternatives."

In their multiple choice items, Linke and Venz (1978) examined the principles of structure of matter, changes of state and solubility and the basic principles of electricity. In their later study Linke and Venz (1979) examined students' misconceptions of the radiation of light and heat, chemical reactions and motion forces. The items, which

contained distractors based on students' identified misconceptions from parallel free response items, were administered to non-science students in Years 11 and 12; the general conclusion was that students completing secondary studies hold identifiable misconceptions or confused ideas.

In order to objectively evaluate first year college physics instruction, Halloun and Hestenes (1985) developed a physics diagnostic test which assessed students' basic knowledge of mechanics. The items were initially selected to assess the students' qualitative conceptions of motion and its causes and to identify common misconceptions already noted by previous investigators. Item distractors were chosen from students' responses identified as misconceptions on earlier tests.

The development of multiple choice tests on students' misconceptions has the potential to make a valuable contribution to the body of work in the area of misconceptions, and to assist in the process of helping science teachers to more readily use the findings of research in their classrooms. It is well documented that research findings in science education take considerable time to be applied in the classroom. Further, if teachers decide to interview their own students to identify misconceptions, this practice itself is fraught with problems since not only is interviewing time consuming, it also requires substantial training.

One way for a science teacher to more easily identify misconceptions held by a group of students would be to administer a pencil and paper multiple choice test which has items specifically designed to identify misconceptions and misunderstandings that arise from earlier teaching and learning prior to commencing the topic or that have occurred following the teaching of the topic. It is, however, well documented that the task of changing misconceptions will not be easy since misconceptions have often been incorporated securely into cognitive structure (see for example, Ausubel, 1978; Driver, 1981; Gunstone, champagne and Klopfer, 1981). Nevertheless, a teacher needs a starting place for addressing known misconceptions and a reliable and valid multiple choice diagnostic test incorporating students' reasoning in selecting responses would appear to provide a relatively straight forward method.

PURPOSE

The purpose of this paper is to describe a methodology for developing multiple choice, two-tier diagnostic tests to identify and evaluate students' scientific misconceptions in specific content areas. Items from two tests will be discussed, one on covalent bonding and structure, an upper school chemistry topic, and a second on photosynthesis and respiration in plants, a biology topic taught in both lower and upper high school.

CONSTRUCTION OF DIAGNOSTIC TESTS

The methodology for diagnosing students' misconceptions in specific content areas is derived from the current literature dealing with cognitive structure and conceptual change, and comprises ten stages involving three broad areas. The stages of the methodology are briefly outlined below; further details are described by Treagust (1985).

- 1) The identification of propositional knowledge and the development of a concept map to define a specific content area in science.
 - . Propositional knowledge statements pertinent to the topic under investigation are identified (see for example, Hackling and Treagust, 1984).
 - . A map of concepts related to the topic under investigation is developed (see for example, Novak, 1980).
 - . The propositional knowledge statements are related directly to the concept map in order to confirm the reliability of the underlying concepts and propositional statements.
 - . The propositional knowledge statements and concept map are content validated by subject matter experts and educators.
- 2) Student misconceptions are identified by examining the relevant literature, by student interviews and by student responses to open ended paper and pencil questions.
 - . The literature is thoroughly examined for related research on misconceptions in specific science content areas.
 - . Unstructured interviews are conducted with a number of students who have recently completed a given topic, in order to identify any misunderstandings and misconceptions.
- 3) The development of multiple choice two tier items, of which the first tier requires a content response and the second tier requires a reason for the response.
 - . Multiple choice items are written based on one or a limited number of propositional statements; students are asked to provide the reason for choosing the particular option of the multiple choice item.
 - . A second-tier of questions is developed for each item based on students' reasons for their choice as well as on information gathered from the interviews. The choice may be the correct answer, a wrong answer or an identified misconception. This technique of two tier items for instrument development has been used by Tobin and Capie (1981).
 - . A specification grid is constructed to ensure that the diagnostic test addresses the propositional knowledge statements underlying the topic.

- Successive refinements of the items in the two-tier multiple choice tests ensure that the tests can be used for diagnosing student misconceptions in the topic under examination.

Based on this methodology, two diagnostic tests from chemistry and biology have been developed by Peterson (1986) and Haslam (1986). The instruments, Covalent Bonding and Structure Test and What do you know about photosynthesis and respiration in plants?, are two tier item multiple choice tests containing 13 and 15 items respectively. Aspects of the test characteristics and details of their use are to be found in Peterson, Treagust and Garnett (1986) and in Treagust and Haslam (1986). Two items, one for each test, are presented below to illustrate how the items work and how the data can be used by classroom science teachers.

USING MULTIPLE CHOICE TESTS TO DIAGNOSE MISCONCEPTIONS

The seventh item of the Covalent Bonding and Structure Test (Box 1) assesses students' understanding of intermolecular forces and is based on three propositions, namely:

- Intermolecular forces, or weak forces of attraction, exist in varying degrees between the molecules.
- Whether a substance composed of molecules exists as a solid, liquid or gas at room temperature will depend on the magnitude of the intermolecular forces between molecules.
- Molecular substances with high melting and boiling points have strong intermolecular forces between molecules.

The data are from responses of four groups of students. Groups 1 and 2 are composite Year 11 and 12 chemistry students respectively in South Australia. Groups 3 and 4 are first year tertiary chemistry students from two institutions in Western Australia. The majority of students in all groups (87%, 97%, 100% and 89%) responded correctly that intermolecular forces account for the differences in state of hydrogen sulphide and water at room temperature. Almost all these chemistry students were aware of the relationship which exists between the strength of the intermolecular forces and the melting point/boiling point of a substance. However, only 11%, 33%, 19% and 18% respectively correctly understand why this relationship exists. A large percentage of students (63%, 40%, 73% and 64%) selected choices 1A or 1B which relate to the strength of intermolecular bonds. These students appear to be making a consistent error and the misconception is easily identified by the teacher using this item. Indeed, the major misconception being addressed, which was earlier identified by interview and in the free

response format, related to the common misunderstanding that "intermolecular forces are the forces within a molecule". A second misconception addressed in choice B of item 7 was that "covalent bonds are broken when a substance changes state". This misconception, selected by 49%, 17%, 30% and 24% of the students respectively, indicates these students have not understood the nature of intermolecular forces in a molecular solid and also the strength of intermolecular forces compared with the forces within a molecule. The misconception is similar to that reported by Osborne and Cosgrove (1983) where students considered that the bonds in water molecules were broken when water changed state.

The second item of What do you know about photosynthesis and respiration in plants? test (see Figure 2) investigates students' comprehension of the gas being taken in by plants when there is no light energy. Specifically this item addresses the following four propositional statements:

- . All organisms, plants and animals, respire continually.
- . Oxygen is taken induring respiration.
- . Photosynthesis takes place only in the presence of light energy.
- . Oxygen gas is given off by the green leaves (or green stems) during the process of photosynthesis.

The first two propositional statements are addressed directly by item 2 while the second two statements are addressed implicitly.

The data are from responses of students in Year 8-10 in one school and from students in Years 11 and 12 in three schools in comparative socioeconomic areas. The results indicate that this sample of students does not have a clear understanding of the process of respiration. When the first part of the item only is taken into consideration (end column), the results show that there is generally an increasingly correct response choice from Years 8-12 (39%, 44%, 41%, 65%, 88%) about which gas is taken in in large amounts by green plants when there is no light energy at all. Taking both parts of the item into consideration, the correct response is much lower (9%, 11%, 7%, 28%, 65%). While there is generally less selection of alternative reasons at each successively higher year level, it is not until Year 12 that responses indicate that this sample of students have a reasonably clear understanding of respiration in plants and even then it is less than acceptable. These results are perhaps surprising when one realises that respiration is taught as an identified topic in Year 8 and is addressed throughout biology units in later years of secondary school. Nevertheless, the results illustrate students' misconceptions and lack of understanding that respiration in plants is an ongoing continuous process during both light and dark conditions.

BOX 1

Item Number 7 from Covalent Bonding and Structure diagnostic test showing percentage of students selecting alternative responses.

Water (H_2O) and hydrogen sulfide (H_2S) have similar chemical formulae and have V-shaped structures. At room temperature, water is a liquid and hydrogen sulphide a gas. The difference in state between water and hydrogen sulphide is due to the presence of strong intermolecular forces between

(1) H_2O molecules

(2) H_2S molecules

Reason

- (A) The difference in strength of the intermolecular forces is due to differences in the strength of the O-H and S-H covalent bonds.
 (B) The bonds in H_2S are easily broken, whereas in H_2O they are not.
 (C) The difference in strength of the intermolecular forces is due to the difference in polarity of the molecules.
 (D) The difference in strength of the intermolecular forces is due to the fact that H_2O is a polar molecule, and H_2S is a non-polar molecule.

Class	Year	N	Choice	Reason				Total
				A	B	C	D	
1	11	159	1	13.8	49.1	10.7*	13.8	87.4
			2	4.4	4.4	2.5	1.3	12.6
2	12	84	1	22.9	16.9	32.5*	25.3	97.6
			2	0.0	0.0	2.4	0.0	2.4
3	13	37	1	43.2	29.7	18.9*	8.2	100.0
			2	0.0	0.0	0.0	0.0	0.0
4	13	37	1	40.0	24.4	17.8*	6.7	88.9
			2	2.2	0.0	6.7	2.2	11.1

* the correct choice and reason response

BOX 2

Item Number 2 from the What do you know about photosynthetic and respiration in plants? diagnostic test showing percentage of students selecting alternate responses.

Which gas is taken in by green plants in large amounts when there is no light energy at all?

- 1) carbon dioxide gas
- 2) oxygen gas

The reason for my answer is because:

- a) This gas is used in photosynthesis which occurs in green plants all the time.
- b) This gas is used in photosynthesis which occurs in green plants when there is no light energy at all.
- c) This gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesise.
- d) This gas is used in respiration which takes place continuously in green plants.
- e)

Year	N	Choice	Reason					Total	
			A	B	C	D	E	No Reason	
8	137	1	14.6	16.8	10.9	16.1	-	2.9	61.3
		2	7.3	10.2	11.7	8.8*	-	0.7	38.7
9	88	1	11.4	5.7	20.5	17.0	-	1.1	55.7
		2	3.4	18.2	11.4	11.4*	-	-	44.3
10	99	1	8.1	11.1	11.2	24.2	4.0	-	58.6
		2	3.0	8.1	23.2	7.1*	-	-	41.4
11	68	1	7.4	1.5	8.8	17.6	-	-	35.3
		2	1.5	1.5	33.8	27.9*	-	-	64.7
12	49	1	-	-	6.1	6.1	-	-	12.2
		2	-	-	14.3	65.3*	4.1	4.1	87.8

* the correct choice and reason response
 - no responses in this category

IMPLICATIONS FOR TEACHING SCIENCE

While reported research on students' misconceptions are inherently interesting and are illustrative of students' thinking and perhaps the failings of the implemented curricula, the results are not easily used by classroom practitioners. One possible means of increasing the application of science education research into the classroom is by utilizing the findings of this research in diagnostic testing. The existence of reliable and valid pencil and paper, easy-to-score, instruments will enable science teachers to better assess students' understanding of science upon which improved teaching can be based.

By using a diagnostic test at the beginning of a specified science topic, a science teacher can obtain clear ideas about the nature of the students' knowledge and misconceptions of the topic. Once misconceptions are more easily identified, a science teacher will be more inclined to remedy the problem by developing and/or utilising alternative teaching approaches which address students' misconceptions.

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CONSTRUCTING AN UNDERSTANDING OF WATER-QUALITY:
PUBLIC PERCEPTIONS AND ATTITUDES CONCERNING
THREE DIFFERENT WATER-BODIES

John Happs

INTRODUCTION

The views that children and adolescents hold about aspects of their world have been increasingly analysed and utilised in teaching strategies over the last decade as science educators have documented student understanding in many areas (Gilbert and Watts, 1983; Osborne and Freyberg, 1985).

In terms of the learner's understanding of natural phenomena encountered within the geophysical environment, relatively little information has been gleaned, with some exceptions in the areas of landforms (Happs, 1982 [a]); glaciers (Happs, 1982 [b]); rocks and minerals (Happs, 1982[c]); soils (Happs, 1984) and weather phenomena (Stepans and Kuehn, 1985). To date, very little emphasis has been placed upon the identification of viewpoints and explanations of natural phenomena, held by adults, although it is tempting to predict that many adults may display an understanding of natural phenomena that is significantly influenced by intuitive views, held during childhood and adolescence (Happs, 1985). Saarinen and Sell (1985), for instance, indicated that the amount of information and warning about the Mount St. Helens volcanic eruption was probably greater than for any previous environmental hazard in United States history yet many people remained unconvinced of the danger since their perceptions of the mountain were in conflict with the scientific perspective.

PUBLIC PERCEPTION OF WATER APPEARANCE AND QUALITY

The appearance of water and perception of water quality in general is seen as a major concern in water quality assessment (Davies-Colley and Wilcock, 1983). Therefore an understanding of human response to water appearance and quality would seem useful in terms of raising public awareness and increasing public contribution to water quality control, whilst relating on-site human response to well-defined measures of water quality.

Perkinson (1979) expressed the view that if the public is to be involved in water

quality planning, then controlling agencies must address the actual concerns perceived by the public and not only the scientific appraisal of the issue.

Intuitively, it might be argued that non-scientists are likely to perceive water quality essentially by visual observation and olfactory response. Thus the public may well decide upon the suitability of water for a particular use, by paying scant attention to measurable factors such as toxic constituents, dissolved oxygen or the presence of bacteria. (David, 1971; Ditton and Goodale, 1973; Nicholson and Mace, 1975). Other workers have identified more complex patterns of response in the judgement of water quality with factors such as educational level (Johnson, 1971), age and confidence in technology, (Kasperson *et al.* 1974) mediating. What is suggested by these studies is the possibility that members of the public might respond to specific cues related to a water-body only if they have not generated prior viewpoints about the water. Thus, first-time visitors to waterways may search for and utilise environmental cues when making decisions about water quality and its general appearance. Residents however may already have constructed definite views about their local water body, being influenced by often unidentifiable sources of information. Such views may prove resistant to change even when the water-body undergoes significant physical, chemical and biological change.

THE INVESTIGATION

In an attempt to arrive at some understanding of the way(s) in which members of the New Zealand public perceive water appearance and quality, investigations were conducted at three different sites:

1. An enclosed lake (Hamilton Lake).
2. An artificial (hydro) lake (Karapiro Lake).
3. A stretch of river close to a city (Waikato River).

These sites were selected since they represented water-bodies at different locations, serving differing communities and offering different recreational pursuits. Within the scope of this paper, only data from Hamilton Lake respondents will be discussed at any length and a limited number of possible mediating factors addressed.

Data were initially extracted from 14 individual interviews with visitors to the lake ($N = 8$) and residents living adjacent to the lake ($N = 6$). Additional information was taken from 50 questionnaires which were completed during the course of further individual interviews with residents and visitors.

Data were collected in an effort to identify:

- (i) the general perception of water quality, as related by a cross-section of visitors to Hamilton Lake;
- (ii) the response of people to Hamilton Lake water both in situ and as a sample for close inspection;

- (iii) the response of casual visitors, regular visitors and residents, in order to ascertain whether, or not, their perceptions of water quality were similar. Visitors' responses were coded V-01 to V-08 whilst residents were coded R-01 to R-06.

Feelings Toward the Lake Domain

All 8 visitors interviewed reacted positively when questioned about their general feelings toward the lake environs, with comments ranging from "good" (V-01), "beautiful" (V-04), "aesthetically very nice" (V-05) to "a good asset to the city" (V-08). No visitor made adverse comments about the lake surrounds and all residents conceded that their view was attractive.

"It's nice to view" (R-05)

None of the residents was totally happy with all aspects of the lake area, with traffic density attracting the main criticism:

"So far as the road's concerned it's the King's Highway - as many trucks and cars and people who want to use it can." (R-02)

The provision of picnic tables and parking bays between residential property and the lake were mentioned as problems by some residents. Most residents considered that they were paying high rates for their situation and this factor seemed to lead to criticism of the Hamilton City Council over a number of matters:

"The high rates that I do (pay) .. and they turn around and let all this go on (points to parking bay across the road). I mean - either take the parking place away or halve my rates..." (R-02)

Feelings Toward the Water Quality

Hamilton Lake is classified as a Class D water body which demands that:

- (a) the pH shall be in the range of 6.0 - 9.0;
- (b) the water shall not be tainted by toxins to the extent that they are unpalatable, unsafe for animal consumption or odorous;
- (c) the natural colour or clarity shall not be changed greatly;
- (d) the concentration of dissolved oxygen shall not go below 5mg/litre.

Visitors' personal feelings about the quality of water from Hamilton Lake were not as positive as those expressed about the lake environment. Six of the visitors were adamant that the water quality was not good and such views tended not to change even when a sample of water was taken from the lake and given to respondents to examine. Water was extracted from the edge of the lake at a point close to where the interviews took place, and where little floating matter was apparent. The water sample was contained in a translucent jug and was rated by the investigator, as being clear and of good quality. The samples resembled tap-water in clarity with minute pieces of suspended algae along with the occasional Backswimmer.

Comments, following close examination of the water included:

"Murky" (V-01); "dirty" (V-04) and "looks pretty grubby" (V-05).

One respondent was a visitor from Holland and he compared Hamilton Lake water with water-bodies that he had observed in Holland:

"In Holland we have really green water - this (points to Hamilton Lake sample) look alright - its good water." (V-07)

Residents were almost unanimous in their criticism of the water and some comments were quite emotive:

"It's a stinking pond across there with flies and bugs and things floating around - dead cats and - you name it." (R-04)

Water samples were taken opposite the resident's home whenever possible. The water quality at this end of the lake appeared to be good with high clarity, low sediment/algae and no odour. When shown an actual sample of water from the lake responses tended to vary with three respondents appearing to use the presented water sample to (imaginatively) reinforce their views that the water was of poor quality:

I "Well what are your comments on that (sample)?"

J "It's very dirty and murky - it does smell - it does look cloudy."

I "Is that more or less what you expected from your experience when you look at that actual sample?"

J "Yes, more or less". (R-05)

The apparent cleanliness of the water sample was noted by one resident who had been rowing on the lake the day before and had been conscious of the water clarity:

I "What's your response to that?" (shows sample)

K "I'm not over-amazed. It does look quite clean."

I "It look quite clean?"

I "Is that more or less what you would expect then (pointing to water sample) - what you see there, or is it worse or better than you expected?"

K "Umm - that's about what I expected." (R-06)

Willingness to swim in Hamilton Lake

Although the majority of visitors described the water sample as dirty and/or polluted, four people (V-02; V-03; V-05; V-07) stated that they would be happy to swim in the lake.

A comparison was made, by one person, between the lake water and public swimming pools:

I "And would you swim in it today?"

R "Oh yes - it's probably no worse than public pools you know." (V-02)

Three of the visitors were clearly opposed to swimming in the lake, of these, two (V-04; V-08) were emphatic:

I "You don't swim in here now?"

R "No - I wouldn't put my big toe in." (laughs)

I "You wouldn't put your big toe in - tell me about that - why not?"

R "It's filthy". (V-04)

and:

"Mothers shouldn't damn well let their kids in the lake - it's dangerous and it's dirty. (V-08)

None of the residents interviewed showed a willingness to swim in Hamilton Lake although two of them indicated that they had been swimming there in the past:

"I can remember as a child at Hamilton Lake here going for a swim but I wouldn't let any child go for a swim now." (R-01)

The other residents were equally definite about not wanting to swim in the lake:

"No, I wouldn't go in there it's too dirty." (R-03)

I "And you haven't been swimming in the lake?"

T "Oh God no (laughs). Those kids on their surfboards - ughh!" (R-04)

"I haven't been in there - it's too polluted really." (R-05)

I "Do you swim in there at all?"

K "Never" (R-06)

Reasons Given for Not Swimming in Hamilton Lake

The four visitors who stated their willingness to swim, or at least paddle, in the lake had no real reasons for considering the water unfit for bathing. However, one comment was made (V-05) about the ducks making some mess in and around the lake.

The ducks were mentioned by each of the respondents not prepared to venture into the water:

"Umm - well I think it (the lake) may be a bit polluted. There seems to be really too many ducks for picnics in comfort. They seem to be all around you. (V-03)

Two visitors (V-01; V-04) linked the ducks to media reports about botulism.

"Yes - botulism amongst the ducks - yes you couldn't swim in amongst all those birds." (V-04)

In addition to the ducks being perceived as a threat to water quality in the lake, one respondent (V-01) expressed much concern about the spraying programme that had been initiated by the Hamilton City Council in order to control the weeds. Later comments were made which indicated a lack of trust toward the local council over the question of spraying:

"They sprayed again - not awfully long after that - maybe 5 years after that - very surreptitiously (laughs) and they swore blind when it was pointed out that they shouldn't have been doing it - that it wasn't a dioxin spray and it didn't have any residual effects, but I can't really see that there'd be any point in spraying unless it was something fairly lethal. It's an ongoing thing. I think the council would spray every year if they were allowed - if nobody kicked up a bobsi-di about it they probably would." (V-01)

The major reasons for residents not swimming in Hamilton Lake were given in terms of rubbish that had been thrown into the lake:

"I think the general society - umm - throwing rubbish and all sorts - which is dangerous." (R-01)

"Too many objects in the water such as tins and bottles." (R-06)

Several residents referred to the presence of rats around the lake and this was attributed to the rubbish thrown into and around the lake:

"I wouldn't know but in the water - you see them - in the rubbish cans fossicking for food and some of them are enormous and they give me the willies." (R-04)

The other three residents gave reasons, for not swimming, in terms of pollution:

"It's too dirty." (R-03; R-04)

and

"It's too polluted really." (R-05)

What did become apparent, to this investigator, was the number of anecdotes that residents drew on in support of their negative feelings toward the water quality.

Weeds were mentioned as a problem in the lake and stories of drownings, because of the weeds, were forthcoming:

I "What happened?"

P "Well he was out in a canoe with a child and the canoe tipped up and - umm - the wife swam out and got the child and thought the husband was behind her and turned around and he wasn't there."

I "And that was a result of what?"

P "Oh - weeds - he got caught up and I do believe we have a weed problem here —". (R-01)

The notion of disease in the water was aired by all residents and reference was made to ducks being killed by botulism:

"We've had botulism in the lake - killing off the ducks in the lake." (R-06)

Botulism was also mentioned by (R-05 and R-02) although the term was sometimes confused:

"I've heard about bubonic [sic] killing ducks off." (R-03)

The respondents linked this lake infection with the death of a neighbour's dog:

I "How did the dog die?"

T "Through the infection in the lake." (R-04)

The sanctioning of lake spraying, in order to control the weeds, was known to all respondents. Some harmful side-effects of the spraying were noted by one resident who was also alarmed over not having been forewarned of the spraying:

"Oh yes - a lot of people get very upset about that because it ruined their vegetable garden too - you know - the drift."

and "We were awakened at 5 o'clock in the morning with "Vrooomm" (laughs) I didn't know what was happening and - umm - I didn't see any notices in the paper". (R-02)

The idea of chemical spraying in the lake was abhorrent to one resident who had several anecdotes to relate about sprays and their deleterious impact:

"My own niece- round the area of Te Kowhata - there they were spraying and my

niece was born abnormal - with a hole in her heart - she lived until 18 months old and died a pitiful death and I just - you know only because of the spray 'cos when she fell pregnant they were spraying around the area." (R-01)

One later facet of this investigation allowed respondents to judge water samples, from the Waikato River and Lake Karapiro, on the basis of clarity and colour (see Happs, 1986). No consensus of estimates was forthcoming and no trends were seen within user groups. Similar disparity was witnessed over respondent's general description of water quality.

SUMMARY

Data from the interviews discussed in this paper, along with other interview data from over 150 respondents at Hamilton Lake, Karapiro Lake and the Waikato River, are documented and discussed in Happs (1986). Overall results suggest that groups such as "residents", "active users" and "passive users" provided varying, and often unpredictable responses to questions concerning water appearance and quality. The influence of media reports, anecdotes and personal bias was evident in many responses with prior "knowledge" and attitudes mediating in decision-making. It seems likely that the whole question of public perception and understanding of environmental phenomena is a complex issue which cannot be reduced to the identification of single variables which determine human response. Rather, a web of interrelated factors may lead to a subjective construction of understanding about water quality. Impartiality and the consideration of available evidence should be important elements in reaching conclusions about water quality. This investigation had led to results which suggest that many members of the public might have difficulty in arriving at objective conclusions about the appearance and quality of water-bodies.

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Research In Science Education, 1986, 16, 216-225.

EXEMPLARY CHEMISTRY TEACHING IN PERTH SCHOOLS

Patrick Garnett

INTRODUCTION

Several case studies concerning science teachers and their classrooms have been reported in the United States (Mitman, Mergendoller, Packer and Marchman, 1984; Stake and Easley, 1978) and Australia (Tobin and Gallagher, 1986). These studies have tended to highlight negative aspects of science teaching and have emphasised the need to improve the quality of science education in schools. Penick and Yager (1983) proposed a series of case studies which focussed on teaching excellence. They hoped that by identifying aspects of science programmes that were successful other "school programmes could begin building on what was known to work". Subsequently a series of monographs has been published which describe exemplary science programmes in American schools (e.g. Yager, 1983).

The present study was one of a series of studies in the Exemplary Practice in Science and Mathematics Education Project (EPSME) conducted in Perth schools. The philosophy of the project is encapsulated in the following extract (Tobin, 1986).

Since this study will focus on exemplary practice in science and mathematics teaching, it should be possible to avoid the situation encountered in so much educational research in which a depressing set of outcomes highlights the plight of science and mathematics education. The outcomes of this study will emphasise effective practices that can be used as models by other teachers. Documentation will be provided on characteristics of curricula and teachers that enable science and mathematics to be successfully taught in contexts that are pertinent to education in Western Australia. If the study is complemented with an effective dissemination process and appropriate in-service programmes, EPSME should lead to improved mathematics and science teaching in Western Australia. Accordingly, EPSME is seen as an important component of ongoing research on improving the quality of mathematics and science teaching.

The purpose of this study was to observe and document classroom practices of year 11 and 12 chemistry teachers who were nominated as outstanding chemistry teachers. It was assumed that teachers nominated as exemplary would be good classroom managers and would demonstrate particular attributes which facilitated student learning and understanding.

METHODOLOGY

Selection of Teachers

Two teachers were selected to participate in the study, one from a government co-educational school and the other from an independent girls' school. Teachers were identified through a nomination process. State education personnel, tertiary science educators and teachers were asked to nominate outstanding teachers of year 11 and 12 chemistry. The two teachers were finally selected because of the frequency with which they were nominated but also because they were identified as having quite different teaching styles.

Data Collection

The methodology employed was similar to the ethnographic approach to classroom observations described by Hamilton and Delamont (1974) and Harding and Randall (1983). Data were obtained from classroom observations, teacher interviews, and student interviews and questionnaires. Multiple data gathering methods and the triangulation of information obtained from different sources and methods were employed to enhance the validity of the study.

Classroom observations

Teachers and classes were observed by the researcher for at least twenty lessons over an 8-10 week period. Narrative records were taken during the lessons to provide a descriptive summary and time log of the classroom activities. As well, teacher-student interactions and management strategies were carefully monitored and recorded.

Teacher interviews

Participating teachers were interviewed formally to establish their teaching value systems, the curriculum and particular aspects of their teaching style. Informal interviews were conducted, as appropriate, to clarify aspects of particular lessons.

Student interviews

A stratified random sampling technique was used to select six students from each class who were interviewed by the researcher. These interviews were used to establish the degree of congruence between the observer's, teacher's and students' perceptions of the teaching activities and classroom environment. Informal questioning of students during lessons was also employed to ascertain students' viewpoints on various aspects of particular lessons.

Classroom environment measures

Student perceptions of the classroom environment were measured using a modified shortened form of the Classroom Environment Scale (Fraser and Fisher, 1983). The scale consisted of twenty-eight items measuring Involvement, Affiliation, Teacher Support, Task Orientation, Competition, Order and Organization and Rule Clarity.

TEACHER PROFILES AND VALUE SYSTEMS

Both teachers involved in this study had strong chemistry and education backgrounds and considerable teaching experience at the upper secondary level. Both were actively involved in professional activities within the science teaching community as members of syllabus committees and the Science Teachers' Association of W.A. They were also regular participants in local professional activities which they regard as an important means of keeping up to date.

Mr S and Mr T share similar major aims in relation to their upper secondary chemistry teaching. Mr S considered his major role was to help students achieve high levels of knowledge and understanding in relation to the chemistry covered in the Tertiary Admissions Examination (T.A.E.) syllabus. He believed that to achieve this aim it was important for students to develop independence and self reliance in relation to their learning.

Mr T also identified the dual aims of developing students' independence and self-reliance and achievement in chemistry. He placed particular emphasis on students developing independent work habits and taking responsibility for their own learning. He believed these to be vitally important and transferable skills for students as they move into post-secondary school situations. Mr T regarded this aim as being of equal importance to students' achievement in chemistry as measured in the T.A.E.

While both teachers had common major aims they perceived their roles in the classroom situation quite differently. Mr S believed he had a critical role to play in expounding on the material in the syllabus, in explaining and promoting student understanding, and in identifying the logical framework of the discipline. He considered that his experience, his awareness of common student difficulties and misconceptions, and his ability to provide relevant examples of chemistry in everyday life were important factors contributing to his teaching effectiveness.

Mr T viewed his role in the classroom as being a much less obtrusive one. He endeavoured to provide a wide range of learning experiences for students and considerable amounts of independent study time so that students could structure their own learning. His role as an explainer or diagnostician was seen much more as occurring on a one-to-one basis.

ANALYSIS OF CASE STUDIES

Detailed case studies of Mr S and Mr T have been reported previously (Garnett, 1986). In this paper several aspects identified as important factors contributing to their exemplary teaching will be discussed.

Activity Structures

The activity structures adopted in Mr S's and Mr T's classes reflected the particular teacher's perceptions of his role. Mr S's classes were generally teacher-centred. The predominant activity structures were whole class non-interactive, whole class interactive, individual seat work, laboratory work and demonstrations. The whole class non-interactive and whole class interactive modes were used predominantly to introduce and explain material, to identify procedures for solving chemical problems, to provide notes where necessary and generally to provide the structure of the discipline. About 25-30% of class time was spent in both the whole class activity modes.

Demonstrations and laboratory work were used quite extensively and account for a further 30% of class time. On some occasions these were used to introduce new work and at other times to illustrate material previously covered in class. About 10-20% of class time was used for individual seat work. In these sessions students usually practised skills such as balancing chemical equations or solving chemical calculations.

Mr T's classes were generally student-centred; much less time was spent in whole class teaching. In his classes a variety of learning experiences was planned and students exercised considerable control over the place at which they moved through the assigned work and, to some extent, over the activities which they selected.

Lesson segments included reading or summarising the text, doing an experiment, working on assignments, watching an audiovisual presentation in the library, doing library research and small amounts of teacher-centred instruction. Student tasks were identified for a lesson or a series of lessons but most of the class time was spent with students working independently or in self-formed small groups.

Teaching for Understanding

An impressive feature of both teachers' classes was the emphasis placed on student understanding. Doyle (1985) expressed concern that in many classes insufficient emphasis is placed on student understanding and learning. He highlighted the problem in classes in which learning and understanding are seen as less important than "getting the work done".

In Mr S's classes important prerequisite knowledge and skills were identified, new material was carefully linked to prior learning, subject matter was clearly explained and common student misconceptions were anticipated and clarified.

Another characteristic of Mr S's classes was his encouragement of student initiated questions. Students consistently sought to improve or test their understanding by seeking clarification or asking questions. Almost all students interviewed identified this as a very positive aspect of Mr S's teaching.

Mr S often used short informal quizzes at the end of short sections of work as a means of assessing the level of understanding and achievement reached by the class as a

whole. These quizzes typically took about 10-15 minutes at the end of a period and provided both the students and teacher with useful feedback.

Mr T believed student understanding was enhanced when students took responsibility for their own learning. He regarded his role as a facilitator of student learning rather than a purveyor of facts, principles and skills.

Mr T identified student-student interactions and the individual assistance he was able to provide to students as important factors which contributed to student understanding. During independent work sessions students often discussed ideas with one another and asked each other questions about things they did not understand. As well, Mr T often asked students questions in these one-to-one situations which probed the students' understanding and provoked them to think about the work and to reflect on their own thinking.

When dealing with difficult topics Mr T identified students experiencing problems and organised remedial activities. A further technique used to enhance understanding was to ask students to apply what had been learned to different and sometimes novel situations. This application-type activity was similar to that suggested in the learning cycle advocated by Karplus (1977).

Both teachers used concrete models to enhance student understanding of particular concepts. Sometimes, as with demonstrations, this enabled the actual phenomenon or concept to be illustrated. When dealing with abstract ideas models were used to simulate the concept. Research evidence suggests that the use of concrete models in this way is positively related to student achievement (Howe and Durr, 1982).

Laboratory Work

Both teachers regarded laboratory work as an essential and integral part of the course. Laboratory work was seen as providing students with concrete experiences which enabled them to better understand concepts and principles developed during the course. As well, both teachers considered that laboratory work played a critical role in the development of students' process and manipulative skills. Experiments were sometimes used to introduce new material and on other occasions to illustrate material which had been previously covered.

Most of the experiments used by both teachers were highly structured in nature but required considerable interpretation and analysis. On some occasions Mr T asked students to design and implement parts of laboratory experiments. During experiments he often asked students questions to provoke them to think about the experiments or their procedures.

During laboratory work Mr S was also actively involved in monitoring students' progress. In a series of experiments on volumetric analysis considerable emphasis was

placed on the acquisition of appropriate manipulative skills. In these experiments Mr S was constantly moving from group to group reinforcing positive aspects of technique and identifying instances of incorrect technique.

Interactions

In Mr S's class much of the teaching occurred in the whole-class mode whereas Mr T utilised independent student work to a much greater extent. Within the whole-class setting Mr S used questions to develop lesson content, to determine students' understanding of material, to check students' performance on assigned class work, and to involve students in sharing ideas. These teacher-initiated questions occurred in a classroom environment which was supportive and free of threat. Students were encouraged to contribute in a manner which lessened the risk associated with an inappropriate response.

A remarkable characteristic of Mr S's classes was the frequency of student-initiated questions. In some classes students asked over 60% of the questions in the lesson. As mentioned previously students tended to ask questions to clarify aspects of the work they did not understand or to obtain feedback on their level of understanding. Sometimes in these interactive sessions students would spontaneously "take over" and answer questions raised by the other students.

In the whole-class setting Mr T used questions to introduce new material and develop the lesson but rarely as a means of obtaining or providing feedback. Mr T preferred to use individual seat work and laboratory sessions to interact with students on an individual or small group basis to obtain feedback.

When the activity structures utilised an individualised or small group arrangement Mr T was constantly interacting with students. Interactions were often initiated by Mr T and often by individual students. Mr T regarded these interactions as being very useful in gaining and providing students with feedback on their progress. He made a conscious effort to talk to each member of the class in most lessons.

During the individual work sessions in Mr T's lessons the students often worked in small groups in which there were high levels of student-student interaction. Mr T encouraged these interactions which he regarded as an important means of students enhancing their understanding of chemistry and of learning to work in a cooperative rather than competitive manner.

Motivation

In a recent review of student motivation, Brophy and Kher (1985) emphasised the importance of maximising students' "motivation to learn". They expressed concern that research findings indicate that many students are much more concerned about completing assigned tasks and achieving high grades than about understanding the content. Brophy

and Kher believe that teachers need to create conditions favourable to the development of student motivation to learn. They suggest ensuring an adequate match between the demands of academic activities and the abilities of the students, encouraging students to ask questions and learn from their mistakes, minimising the salience of the teacher's authority figure role and of testing and grading, and using praise and rewards, if at all, according to prescribed guidelines.

Students in both teachers' classes in this study demonstrated high levels of motivation to learn. While students identified the T.A.E. as an important motivating factor it was clear that both teachers had established environments which fostered the development of students' motivation.

Another feature common to both teachers was the nature of student feedback following tests and examinations. Students were not compared with one another but their performance was discussed in terms of their level of achievement, in relation to perceived effort, and in relation to prior performance. Each of these types of feedback are included in Brophy and Kher's guidelines for effective praise.

Students in Mr S's class commented on his obvious interest in and enthusiasm for the subject and identified this as an important factor in enhancing student motivation. As one student commented:

"He obviously enjoys what he's doing. He shows a lot more interest and enthusiasm than many of my other teachers."

Management, Engagement and Classroom Environment

Observation of both teachers' classes provided evidence of high levels of classroom management skills. Goals were clearly communicated to students and lessons ran smoothly and effectively. High levels of "with-it-ness" and "overlappingness" (Kounin, 1970) were evident.

Concomitant with these well refined management skills were very high levels of student engagement. Typically engagement levels were over 90% in Mr S's classes and over 80% in Mr T's classes. Careful time management through prompt starts to lessons and minimising time lost in transitions, together with high levels of student engagement are important variables in predicting student achievement (Berliner, 1984). Mr S placed considerable importance on obtaining high levels of student engagement and on the efficient use of class time. Students who strayed off task were quickly identified and brought back on task. In Mr T's class, where large amounts of time were devoted to independent and small group work, Mr T constantly moved around the class interacting with individual students, helping, encouraging and generally maintaining high levels of student engagement. Other research evidence suggests that the monitoring of students, particularly while working individually, is important in fostering high levels of engagement and academic achievement (Fisher, Berliner, Filby, Marliave, Cahen and Dishaw, 1980).

Classroom measures indicated high levels of task orientation in both teachers' classes. These high levels of task orientation were consistent with the high quality management skills and clear expectations of student behaviour in these classes. Students were expected to work hard, to understand and enjoy the subject and to obtain high levels of achievement. These expectations have been identified as significant variables in enhancing student achievement (Brophy and Good, 1974).

Mr S and Mr T both established positive and supportive classroom environments in which learning could take place. Students were encouraged to be responsible for monitoring their own learning but classroom environment measures indicated that this occurred in situations in which high levels of teacher support were provided. The genuine care and interest both teachers demonstrated in their students' welfare and development was identified by students in both classes. As a student in Mr T's class said:

"Mr T helps you and guides you ... (he) wants you to try and do the best for yourself that you can".

CONCLUSIONS

Within the present study it was clear that exemplary chemistry teaching practice was occurring in both Mr S's and Mr T's classrooms, although the nature of the instruction was quite different. While it is difficult to generalise from two case studies it is informative to make comparisons and to speculate on the essential ingredients required for exemplary practice.

Both teachers in this study had strong chemistry backgrounds, were very experienced teachers and were professionally active within the science education community. It seems that these three characteristics are likely to be shared by most outstanding chemistry teachers.

The teachers observed in this study had quite different perceptions of their classroom roles. As a result the types of activity structures employed and the times spent in these differed considerably. Both teachers however adopted teaching styles which were compatible with their own particular philosophy and which they believed best achieved their objectives. This suggests that curriculum developers should produce materials which are flexible and able to be used in quite different situations by teachers with different personalities and teaching styles.

A characteristic of both teachers was the emphasis placed on facilitating student understanding. This was an important objective, although the methods by which this was achieved were often quite different. One teacher very carefully presented and explained new material while the other provided carefully planned experiences from which students structured their own learning. In both cases, however, the lessons were carefully linked and sequenced, and concrete models were used to facilitate understanding.

Probably the most critical factor contributing to student understanding in both teachers' classes was the provision of feedback. Students obtained regular feedback on their progress and understanding through a variety of methods including written solutions to exercises and tests, teacher-class questioning and individual teacher-student and student-student interactions.

Students in both teachers' classes exhibited high levels of motivation. The T.A.E. was identified as a powerful motivating force and within that context the teachers established positive and supportive classroom environments in which students were encouraged to achieve their full academic potential. Both teachers placed considerable emphasis on students developing self-reliance and responsibility for their own learning. The classroom environment established and the degree of teacher support were important factors contributing to the students' development of this responsibility.

Both teachers observed in this study exhibited very effective time management skills. This resulted in minimal wastage of class time and high levels of student engagement. Although the teachers characteristically used different activity structures both used appropriate monitoring procedures to identify and redirect students who were off-task.

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Research In Science Education, 1986, 16, 226-232.

INTEGRATING SCHEMATIC REPRESENTATIONS OF KNOWLEDGE: A THEORETICAL STIMULUS TO SCIENCE EDUCATORS?

Jack Rowell and Chris Dawson

"...research on cognitive skills has taught us in recent years ... that there is no such thing as expertness without knowledge - extensive and accessive knowledge. No one, no matter how intelligent, skilled in problem solving, or talented, becomes a chess grandmaster without 10 years of intense exposure to the task environment of chess. Hence in the training of professionals, the problem of coverage cannot be avoided. We cannot produce physicists without teaching physics ..." (Simon, 1980, p.82).

The statement of Simon encapsulates the essence of a great deal of recent research in cognitive psychology and artificial intelligence (AI). Problem solving in a given subject matter, especially high level problem solving, requires extensive, organized domain-specific information - a knowledge organization which is only acquired through considerable and serious experience within the subject. But such knowledge organizations are not confined to academic problem solving. There is a wealth of evidence that they are constructed also in the normal course of our interaction with the world, and provide the basis of many of our day-to-day expectations, evaluations, inferences and actions.

What are the characteristics of these knowledge organizations, and how are they to be presented?

From their own research with young children, and a great deal of other work to which they refer, Nelson, Fivush, Hudson and Lucariello (1983) note such characteristics as; fusion of details of particular, similar experiences; confusion of similar repeated experiences [Neisser's (1981) report of the confusions and fusions of John Dean's memory for details of the Watergate coverup and cited as a 'classic' example]; selection (of parts of stories recalled); and repair (of misordered narratives). Abelson (1981), points to the false recognition of nonmentioned events, and notes also the important characteristics of hierarchical structuring of knowledge organization. (See also Chi, Glaser & Rees (1982)). Hinsley, Hays and Simon (1972) comment on classification, and Larkin (1980), referring to that study, notes how respondents were able "... from a tiny element of the problem, 'a

river steamer' ... to activate an entire unit describing a particular kind of problem ... and probably even a large part of its solution..." (p.118).

The form of knowledge organization suggested as encapsulating these characteristics has been given the name 'schema'. It can provide a unitary representation of both declarative (factual) and procedural knowledge (Chi & Rees, 1983, p.93), although representations making an explicit distinction between the two are equally possible (Chi & Rees, 1983, p.90). Nelson and her colleagues (Nelson et al., 1983, p.53), describe schemata as "...spatially-temporally organized sets of expectations about what things will look like or the order in which events will occur. These expectations are organized in terms of a series of variables, or slots, which can be instantiated with greater or lesser degrees of probability by a range of values." The idea is that, when activated by incoming data (for example, as above, by 'river steamer') the schema then operates in a top-down conceptually driven manner, giving meaning to material, guiding attention to relevant data, filling gaps and even overriding inconsistent data. "If a situation does not provide enough information to instantiate a variable, the values of other variables as well as expectations about allowable and probable values can lead to the assignment of default values. Comprehension and recall of schematically organized material is therefore highly inferential in nature and can even produce distortions in memory" (Nelson et al. 1983, p.53; see also Chi & Rees, 1983, pp.88-90). Clearly, the schematic organization of knowledge is considered a powerful one. So powerful, in fact, that Nelson (Nelson et al., 1983, p.67), hypothesizes that a schematic representation may make logical inferences and causal reasoning unnecessary. That is, a schema once activated may provide the causal chain and the missing parts so that "What looks like high-powered reasoning is actually the result of having a well-structured mapping available" (p.67). Certainly the hypothesized existence of experientially-based, content/context dependent schemata provides a degree of understanding of a considerable amount of data relevant to thinking, including our own work concerned with the study of control of variables problems (Dawson & Rowell, 1986). In that study we did find that some students demonstrated consistent, abstract planning and interpretation skills but, in the main, responses were dominated by a general inconsistency. Different problems tended to elicit different solution procedures, appearing to reflect an individual's prior knowledge organization of content-related information - sometimes quite specific, sometimes more general.

Despite the evident power of the schematic representation in relation to domain-specific knowledge it is apparent in our own work (as cited above), and in that of others (for example, Rosch, 1983; Read, 1983; Nelson et al, 1983; Larking, 1980), that an ability does exist in people, some more than others, and developing with time, for logical reasoning which is progressively more content independent. Nelson (p.68) describes this as

"... the increasing distancing of the child from familiar personal experience and the increasing ability to perform in domains that are free of spatiotemporal context, external or internal." The distinction, but possible relation, between reasoning based on specific known events and reasoning based on logic is an important one, and for more than one reason. Theoretically it is important because it demands an explanation. More pragmatically we, as teachers, need to be aware of the distinction, the characteristics of both, when each is likely to be activated, and their interrelations, so that we may promote both in appropriate circumstances.

What is the connection? Chi and Rees (1983), in a paper concerned with outlining a learning framework for development, assert that knowledge in the sense of factual content, and knowledge in the sense of abstract abilities and logical structures are on 'separate and different planes'. Further, they assert that 'traditional Piagetians' have exclusively dwelt on the latter. We shall argue, briefly, that this view of Piaget's work is too limited, and denies, or ignores, the potential of his post 1972 theoretical elaborations. Accordingly we shall propose a rapprochement between Piaget's theory and the schematic ideas outlined above, allowing a theoretical connection between the two forms of knowledge and a basis for their combined understanding.

In 1972 Piaget explicitly recognized the possible content dependency of formal thinking. Subsequent to that revelation he developed his new theory of equilibration, and expanded his ideas of abstraction and generalization, and consciousness, as precursors to an elaboration of his theory of two systems of knowing, concerned respectively with understanding (System I) and succeeding (System II) (Piaget & Vuyat, 1979; Vuyk, 1981, p.141). Throughout this time the importance of factual knowledge as an aspect of his theorizing increased steadily - a matter we have addressed elsewhere (Rowell & Dawson, 1986). Space precludes a further elaboration and we shall confine ourselves here to outlining Piaget's two systems of knowing as the touchstone for a rapprochement with the schematic ideas of cognitive psychology and AI: other aspects of his theory will only be called on as and when they are required.

The two systems of knowing, System I (understanding) and System II (succeeding) are concerned with knowledge organization and knowledge change, where 'knowledge' may be interpreted to mean both factual and procedural content and logical capability. Piaget incorporates these senses of knowledge by considering the two systems as based on three types of schemes and their combination. Thus, the system of understanding is conceptualized as composed of presentative schemes (principally 'representative', but Piaget uses 'presentative' because he includes sensorimotor schemes) and the presentative (or structured) aspect of operational schemes. System I, then, constitutes 'the real' for the individual. Through System I the individual understands the world, or misunderstands it,

and it is in relation to System I that knowledge gaps or disequilibria are produced; that is, through which s/he recognizes problems and, through the operation of equilibration, makes progress in understanding. System II, the system of succeeding, consists of procedural schemes and procedural (transformational) aspects of those operational schemes available to the individual. Like presentative schemes, procedural schemes are coordinated among themselves, but not through equilibration. Rather, the "... means involved consist essentially in correspondence and transfers of methods, which eventually encourage the formation of new procedures by allowing comparisons with those which have worked effectively in other situations" (Piaget & Vuyat, 1979, p.72). Unlike structures, because procedures are goal-directed they are also transient (Piaget & Vuyat, 1979, p.74). That is, once a goal is reached, the procedure no longer exists as such. Piaget emphasizes the importance of this 'aspect of perpetual renewal'; it is, he says (p.74), "...precisely what qualifies it for its role as a tool of reequilibration." How is this to happen? Through the operation of System I the individual recognizes a knowledge gap (a problem or disequilibration of some sort). In striving to fill that gap, Piaget (Piaget & Vuyat, 1979, p.73) describes the conditions under which solutions are generated. First, essentially due to the operation of System II, possibilities are generated as the goal-directed products of free combinations between problems and procedures, which may be systematic or haphazard to any degree. Second, because such a modus operandi must generate errors as possibilities as well as successful solutions, ways of selection must operate. These, says Piaget (p.73), take account of the results obtained from procedures already tried, the understanding of the individual (System I), and procedural schemes susceptible to transfer which have proved their value in other situations (see also, Vuyk, 1981, pp. 176-177). "Generally speaking, then, the opening up of new possibilities amounts to the transcendence of a given state of affairs in the direction of a new reality, rich in possible actualizations, and thus that much better equilibrated conceptually" (Piaget & Vuyat, 1979, p.74). System I is enriched by the process since the resultant goal-directed solution becomes a presentative scheme, as does the procedure "... in those cases where it later gives rise to a mental reconstruction (memory, understanding of the reasons for a successful outcome, etc.)..." (Piaget & Vuyat, 1979, p.74).

In the course of his account of Systems I and II and their operation Piaget provides two descriptions of presentative schemes. They are, as above, the goal-directed, gap-filling products of the operation of equilibration. Elsewhere (p.71) he describes them as derived from the permanent and simultaneous characteristics of comparable objects, and cites the representational concepts 'squares' and 'cats' as exemplars. What is the connection? In a different context Abelson (1981, p.725) supplies a possible part answer, and a compelling connection to the schemata of the cognitive psychologists and followers

of AI. Employing current category theory (Rosch, 1983; Wittgenstein, 1953) Abelson points out that scripts (= schemata) can be regarded as psychological categories in just the same way as can concepts constructed from objects such as chairs, and share equally in the possibility of hierarchical organization. Both sets of categories may be regarded as constructed via family resemblances between attributes, not, as previously believed for concepts, by the all or nothing possession of a set of criteria. Family resemblance refers to the overlapping of attributes among specific realizations of a concept or schema; there is a sharing of attributes, though not necessarily the same ones. The most prototypical realizations of a concept, or schema, then are the ones embodying more of the most commonly experienced attributes. Abelson's arguments concerning scripts apply equally to the goal-directed problem solutions of Piaget, and an equivalence is apparent with the second description of presentative schemes as object concepts. They are psychological categories sharing the property of family resemblance in their construction. Elsewhere (Rowell & Dawson, 1986) we have described how family resemblance appears to be involved in the Piagetian procedure of inductive generalization - a generalization from 'observables' resulting in a scheme, and level of understanding, with characteristics very similar to those of the cognitivist's schemata. Indeed, we propose there is nothing in the nature of cognitive schemata which distinguishes them from inductive generalizations in the Piagetian sense, and prevents their integration with that viewpoint. However, the Piagetian viewpoint is concerned with more than empirical abstraction and inductive generalization, it is concerned also with reflective abstraction and constructive generalization; that is, with the generation of theoretical frameworks and explanations. Thus, for example, one may consider as presentative schemes two levels of understanding of Boyle's law, one derived from the empirical 'reading off' of observables and their relations, and the other a theoretical (logical) derivation from the operational constructions of the child together with some conceptualization of matter and void. In the former instance an operational framework is being applied to reality, in the latter it is being attributed to it, leading to a "... new formal content consisting of inferential coordinations which go beyond the observables" (Vuyk, 1981, p.135). The latter explains the former. In short, Piaget's work has the potential for representing the interaction of logical reasoning capability and reasoning based on specific known events sought by the cognitive schematists - although there is still a long way to go before the current generalities become predictive of specific situations.

In proposing the integration of schematic ideas with Piagetian psychology we recognize that we may be exceeding the limits of acceptability of their separate authors. But there are advantages to the union. Psychology gains in that it moves towards a more unified, comprehensive system of explanations - a fundamental principle of progress

according to Carloye (1985, p.255). Piagetian theory gains by the addition of greater specificity. Schematic ideas (of cognitive psychology and AI) progress through incorporation in a far reaching psychological framework within which their formation and functioning gain in meaning. And science education gains in that the integrated framework provides the potential for further advances in practice. We have elaborated these points elsewhere in more detail than is possible here (Rowell & Dawson, 1986), but much remains to be done. Our hope is that you, the reader, will be stimulated to reflect on our ideas, and to consider their worth as a theoretical step forward and as a basis for directing (or re-directing) practice in science education.

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Research in Science Education, 1986, 16, 233-235.

RESEARCH NOTES

These notes contain brief references to a number of presentations at the 17th annual conference of the Australian Science Education Research Association. More detailed texts or manuscripts may be obtained from the authors.

1. An evaluation of the use of a programming grid in the science curriculum, Patrick Cronin, St. John's College, Whyalla, S.A.

This paper deals with a programming grid as a tool for the development of a science programme in a school. Recommendations are made on how to expand the grid, organization of in-service workshops and the development of language analysis techniques for teachers.

2. School Science; Social purposes and liberal values, Rod Fawns, University of Melbourne.

School science was originally composed by academic scientists and textbook authors out of what they conceived to be the most important, or the simplest part of their subjects. They made a sort of anthology of science. The professionalization of science and science teaching clearly has been served by school science. But why has school science remained an anthology of essential definitions?

3. The repertory grid as an alternative/complementary probe in science education, John Happs, Western Australian College of Advanced Education, & Keith Stead, Gippsland Institute of Advanced Education.

The current interest in the ideas pupils bring to their science lessons has led to the exploration and development of a variety of techniques to reveal these 'naive' ideas.

This paper provides illustrations of the use of the "Repertory Grid" in two different areas of interest in science education. The first examines aspects of a pupil's outlook on science, and the second examines aspects of a pupil's understanding of rocks and minerals.

4. Scientists in the making, Jan Harding, Chelsea College, University of London.

School science is all too frequently presented as a set of abstracted immutable laws enabling control but divorced from emotional response. As such it offers a refuge for the emotionally reticent male, but has little meaning for the female. Many of the girls who do choose science see in it a way of making a contribution to the world.

Analysis suggests that not only values, but cognitive approaches, may differ. The male may seek generalizations and work by isolating and controlling variables - a method used with considerable success in the physical sciences. Recent studies of a few women scientists working within the life sciences suggest they approach their material with greater humility and a sense of identification with it.

The implications for curriculum development and for research in science education are examined.

5. Effects on science achievement of students' use of computers, Heather Payne, Australian Council for Education Research.

As part of the Second International Science Study in Australia, data were collected on the distribution of computers in students' homes and in their schools. This paper examines the data showing the distribution of computers in the homes and schools of students in Australia, and looks at characteristics of the students who are using computers frequently. The associations between the frequency with which students use a computer and their science achievement and attitudes to the importance of science is explored.

6. Polynesian students' outlooks on science, Keith Stead, Gippsland Institute of Advanced Education.

This paper provides a further example of the application of the Theory of Reasoned Action (TRA) by seeking an explanation for the under-representation of Polynesian students in the sciences. These TRA insights are complemented by data collected from interviews conducted with the parents of Polynesian students.

These approaches suggest the term "Polynesian" needs to be seen as encompassing at least two distinct subgroups, the Maori and the Pacific Islander, and that different mechanisms appear to be responsible for each subgroup's under-representation in the sciences.

7. Roger Osborne and the Australian Science Education Research Association, David Symington, Victoria College, Toorak Campus and Keith Stead, Gippsland Institute.

How does one evaluate the effectiveness of an organization such as the Australian Science Education Research Association? This paper casts some light on this question by examining the interaction between the Association and aspects of the professional activity of the late Roger Osborne.

It is argued that such an analysis indicates that in Osborne's case the Association has achieved its aim but that this is due, in no small measure, to Osborne's ability to capitalize on the opportunity arising from his membership of the Association.

8. Equity versus quality: Problems in selecting students for science teacher education programmes in developing countries, Euwe van den Berg, c/- Science and Mathematics Education Centre, W.A.I.T.

Secondary schools in developing countries generally show a far wider range of quality than those in the so-called "developed" countries. This creates serious problems in admission to tertiary institutions. Admission tests usually produce a ranking which closely follows the ranking in school quality, however, both politically and educationally this is not acceptable. Further, ethically one would like to create some upward mobility and give opportunities to disadvantaged kids. The above problems are not unlike admission problems involving minorities in Western countries including Australia.

This paper describes admission test and policy research carried out in Indonesia for the past 5 years and compares it with work done in African Countries.

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 Note 1, J.J. Smith, personal communication
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